NERMN Estuary Water Quality Report 2014

Bay of Plenty Regional Council
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5 Quay Street
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Whakatāne 3158
NEW ZEALAND

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Executive summary

The purpose of this report is to document the water quality state and trends in the estuaries of the Bay of Plenty. Estuarine water quality is monitored in nine of the larger estuaries under the Natural Environment Regional Monitoring Network (NERMN). Over ten water quality parameters measuring biological, aesthetic and chemical properties are monitored at 24 sites every two months. The data extends as far back as 1990 enabling conclusions to be drawn on long-term trends in water quality.

The objectives of this monitoring programme align with the policies and objectives of the Regional Water and Land Plan (RWLP) and the Bay of Plenty Regional Coastal Environmental Plan (RCEP). These objectives include:

- Determining the state and trends in estuarine water quality.
- Assessment against national and regional water quality classifications and environmental standards for riverine and coastal estuaries.
- Identify potential causes of poor water quality.

River estuaries

The Kaituna, Tarawera, Rangitāiki, Whakatāne and Ōpōtiki are the smaller riverine estuaries (river mouths) dominated by freshwater flow and tend to have higher nutrient and bacterial levels. The most common trend among these estuaries has been a decrease at four sites in ammonium nitrogen concentrations (see Table 1). However this tends to be balanced by an increase in oxidised nitrogen (TOx-N) at Kaituna, Tarawera and Rangitāiki with no change in total nitrogen concentrations. These three estuaries also have high average nitrogen (TOx-N) levels above relevant ANZECC guidelines. Average concentrations of dissolved phosphorus (DRP) increased at four sites but total phosphorus only increased at Rangitāiki.

Chlorophyll-a is used as an indicator of primary productivity and is highest in the Kaituna River estuary, followed closely by the Rangitāiki River estuary. Both estuaries have average levels below relevant ANZECC guidelines. Ōpōtiki (Kukumoa) Estuary shows an increase in chlorophyll-a, but concentrations are also well below ANZECC guidelines.

The faecal contamination indicator, *E.coli*, exceeded the Water Quality Microbiological Guidelines red alert mode (550 cfu/100 ml) on at least one occasion for all but one river estuary. Median values of *E.coli* for all estuaries are well below the 260 cfu/100 ml orange alert mode indicating that the estuaries are generally safe for contact recreation.

Ōhiwa/Maketū/Waihī estuaries

These three estuaries are moderately sized tidal lagoons, with moderate freshwater inflows and over 70% of their intertidal area exposed at low tide. Average turbidity for these three estuaries (2006-2011) is below ANZECC guidelines (10 NTU), with Port Ōhope, Ōhiwa being highest (6.8 NTU). High turbidity in Ōhiwa Harbour is linked to soil erosion which adversely impacts the harbour ecosystem.

Average dissolved and total phosphorus levels for all three estuaries are below the ANZECC guidelines, but 25% of the individual total phosphorus results for Port Ōhope exceed the guideline. Maketū Estuary has the highest average ammonium concentrations which exceed ANZECC guidelines. Average TOx-N concentrations are also above the ANZECC guidelines in Waihī and Maketū estuaries which are potentially related to the moderate freshwater inflows and intensive land-use.

Waihī Estuary has higher bacterial numbers compared to Maketū and Ōhiwa, but all three estuaries meet bathing water quality guidelines 95% of the time. All measured bacteria (*E.coli, faecal coliforms and enterococci*) have been showing an increasing trend at Waihī Estuary and the Ruatuna Road, Ōhiwa Harbour site.

Tauranga Harbour

The most consistent trend seen in water quality results for Tauranga Harbour is a decrease in total phosphorus concentrations at five of the ten sites in the southern harbour and a decrease in dissolved phosphorus at three sites. Kauri Point and Maungatapu had the highest median total phosphorous concentrations (for the 2006 - 2011 period) which are below the ANZECC guideline levels. At most sites, dissolved inorganic nitrogen (TOx-N and NH_4-N) tends to be above the ANZECC guideline, which may not be appropriate given that open coastal waters have a similar concentration.

Pahoia, in the upper reaches of the southern harbour, has the highest median chlorophyll-a concentrations followed closely by its northern counterpart, Kauri Point. Spring-summer concentrations of dissolved phosphorus are lowest at these sites indicating that this nutrient may also limit potential phytoplankton and macro-algae production. Three northern harbour sites showed increases in chlorophyll-a concentrations which is an indicator of phytoplankton production.

The highest average suspended solids and turbidity values occurred at Pahoia, Otumoetai and Te Puna with maximum values highest at Pahoia, Te Puna and Ōmokoroa. While maximum turbidity results have been above the ANZECC guideline (10 NTU) at five of the 13 sites in the harbour, three quarters of the data is below this level for all sites. This shows that overall water clarity is good.

When compared with the Microbiological Water Quality Guidelines, faecal indicator results show that the microbiological water quality of Tauranga Harbour is generally good. Elevated results exceeding safe recreational limits occasionally occur, and are often associated with rainfall or contamination events such as sewage overflows. Increasing trends in Tauranga Harbour are at sites in close proximity to the Wairoa River, the largest freshwater inflow.

Table 1 Number of significant water quality trends for Bay of Plenty NERMN Estuary Sites.

	Suspended solids	Turbidity	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Chlorophyll-a
River Estuaries											
6 Sites	▼	▼▼ ▼	▼▼ ▼▼	▲▲ ▲		▲▲ ▲▲	▲	▼	▲	▼▽	▲ ▼
Eastern & Central Estuaries											
4 Sites	▲▲						▼	▲▲	▲▲	▲▲	
Tauranga Harbour											
Southern Harbour - 10 sites	▲▲ ▲	▼	▲	▲▲ ▼	▲	▼▼ ▼	▼▼ ▼▼▼	▼▼ ▲	▲▲ ▲	▲▲	▼ ▲
Northern Harbour – 3 Sites	▲			▲							▲▲

▲ = meaningful increase; △ = significant increase; ▼ = meaningful decrease; ▽ = significant decrease.

Conclusion and recommendations

Some estuarine sites in the Bay of Plenty show declining water quality trends while other sites show improvements linked to reduced impact from point source discharges. The complexity of estuaries and their sensitivity to stressors means that it is often difficult to assess their state and few appropriate guidelines are available. The key recommendations from this report are to:

- Develop water quality guidelines and/or criteria for Bay of Plenty estuaries.
- Create better links with fluvial (river and stream) and estuarine ecological monitoring.
- Investigate minimum flows (including groundwater) required to sustain estuarine salinity gradients.
- Ensure that the setting of water quality limits for freshwater (as part of implementation of the National Policy Statement for Freshwater) takes account of the effects on estuaries.

Contents

Part 1: Introduction

1.1 Overview

Estuaries form a transitional environment between the land and the sea mixing together fresh and saline waters. In these unique coastal environments different mixtures of oceanic and freshwaters create many different habitat types, supporting an abundance of animal and plant wildlife. They form an important resource for human cultural and economic development.

High levels of development pressure means that estuaries are subject to a range of direct and indirect impacts due to land use in the catchment, changes to hydrology and the direct use of the estuary waterways. The greatest influence in many estuaries is that of oceanic waters constantly draining in and out of an estuary with the changing tides.

Nutrients, sediments and toxins that originate within a catchment as a result of urbanisation, agricultural activities, vegetation clearing and industry, eventually end up in estuaries potentially affecting the water quality and estuarine ecosystem. As such, estuaries are often a sink for sediments and associated contaminants from such discharges. Our larger coastal estuaries are influenced by discharges that stem from multiple river, streams and storm water discharges. Estuarine health largely reflects activities in the catchment.

1.2 Purpose

The purpose of this report is to document the water quality state and trends in the estuaries of the Bay of Plenty. Estuarine water quality is monitored under the Natural Environment Regional Monitoring Network (NERMN) and this covers a range of physico-chemical and microbiological properties. The data extends as far back as 1990 enabling conclusions to be drawn on long-term trends in water quality.

The policies and objectives driving the monitoring programme are found in the Regional Water and Land Plan (RWLP) and the Regional Coastal Environment Plan (RCEP). The RCEP is going through a review which may impact some aspects of water quality monitoring in Bay of Plenty estuaries. The key objective of the RCEP is the 'maintenance and enhancement of the water quality and mauri of the Bay of Plenty coastal marine area'. The policies and objectives found in these two plans form the *objectives* of the monitoring programme, which are to:

- Determine the quality of estuarine waters in the Bay of Plenty and water quality trends.
- Compare water quality against relevant water quality classifications (standards) for riverine and coastal estuaries.
- Identify potential adverse effects on water quality in the receiving environment.

The water quality classifications (standards) are described in Appendix 2 of this report. The anticipated environmental results from implementation of the RCEP most relevant to the objectives of this report are:

- Safeguarding the life-supporting capacity of coastal water and coastal ecosystems.
- Water quality in harbours and estuaries is maintained and enhanced.

- Reduction in human induced sedimentation within harbours and estuaries.

Part 2: Methods

2.1 Sites

Nine estuaries are currently monitored under the NERMN programme. Twenty-one sites are sampled every two months over the high tide period and three sites over the low tide period. Dissolved oxygen (near the surface), temperature and salinity are measured in the field and samples are collected for analysis of turbidity, suspended solids, conductivity, salinity (laboratory), pH, chlorophyll a, nitrate-nitrogen, ammonium-nitrogen, dissolved reactive phosphorus, total phosphorus, and indicator bacteria. Laboratory methods for analysis are listed below.

Table 2.1 Location details for estuarine monitoring sites.

Site No	Description	Estuary	NZMS 260 Map Ref
BOP150001	Kukumoa	Ōpōtiki Estuary	W15:8500-4750
BOP150017	Opotiki Wharf	Ōpōtiki Estuary	W15:8600-4670
BOP150002	Ruatuna Road	Ohiwa Harbour	W15:7340-4550
BOP150003	Port Ohope Wharf	Ohiwa Harbour	W15:7090-4940
BOP150004	Boat Ramp	Whakatane Harbour	W15:6240-5420
BOP150018	Jetty at Boat Ramp	Rangitāiki River	W15:5100-5840
BOP150019	50 m d/s of Matata/Thornton Road	Tarawera River	V15:4320-6060
BOP150006	50 m offshore from Domain	Waihi Estuary	V14:1680-7650
BOP150005	Boat Ramp	Maketu Estuary	V14:1460-7700
BOP150020	River Diversion Structure	Kaituna River Estuary	V14:1100-7730
BOP720004	Kulim Ave, Otumoetai	Tauranga Harbour	U14:8880-8870
BOP720001	Grace Street	Tauranga Harbour	U14:8950-8390
BOP150011	Maungatapu Bridge	Tauranga Harbour	U14:9140-8340
BOP730024	Waipu Bay (Boat Ramp)	Tauranga Harbour	U14:9080-8770
BOP150021	Wharetoa (Toll Bridge Marina)	Tauranga Harbour	U14:9050-8750
BOP150012	Otumoetai, Beach Road.	Tauranga Harbour	U14:8732-8854
BOP150013	Te Puna, Pitua Road.	Tauranga Harbour	U14:8230-8920
BOP150014	Omokoroa, Wharf.	Tauranga Harbour	U14:7980-9210
BOP150026	Pahoia Beach Road	Tauranga Harbour	U14:7515-9236
BOP150023	Kauri Point Jetty	Tauranga Harbour	U13:7328-0509
BOP720025	Ongare Point.	Tauranga Harbour	U13:7290-0680
BOP150027	Tanners Point Jetty	Tauranga Harbour	U13:7087-0930
BOP150022	Bowentown Boat Ramp	Tauranga Harbour	U13:7320-1186
BOP150030	Pilot Bay	Tauranga Harbour	U14:9090-9081

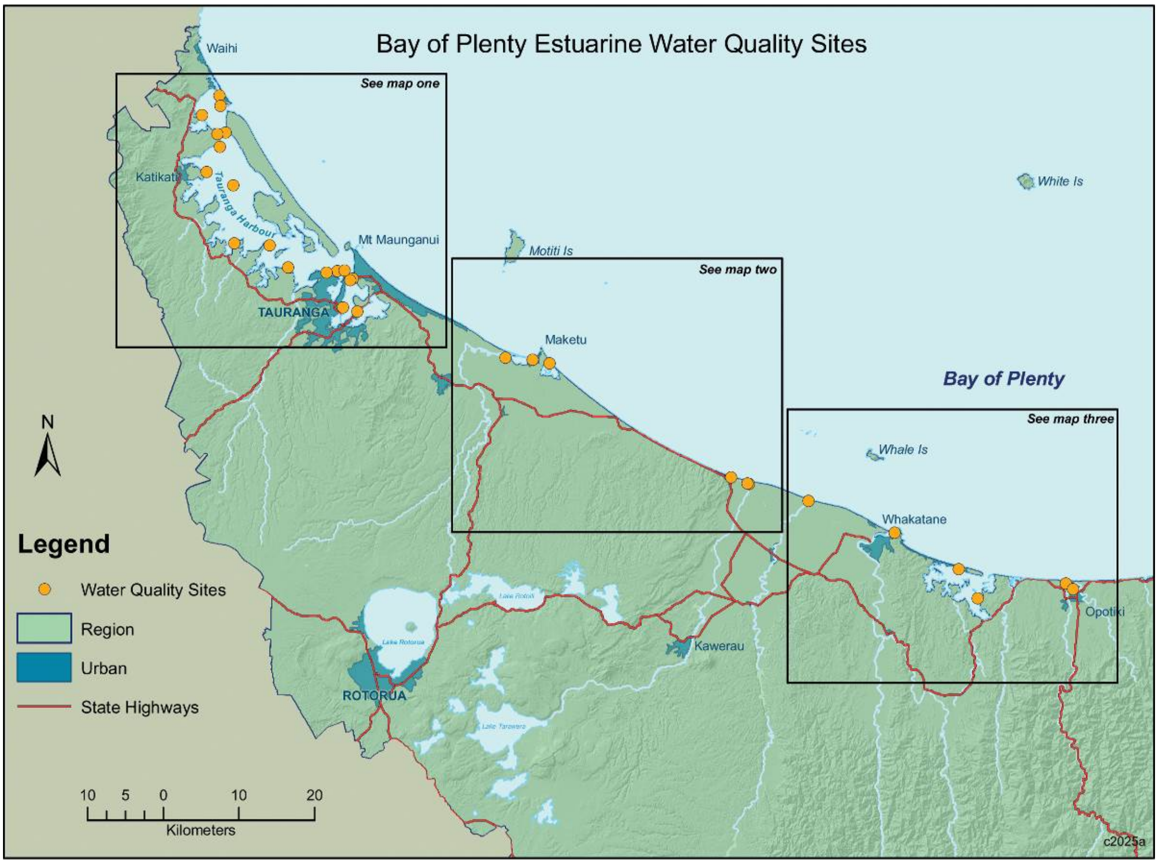


Figure 2.1 Estuary monitoring sites, Bay of Plenty.

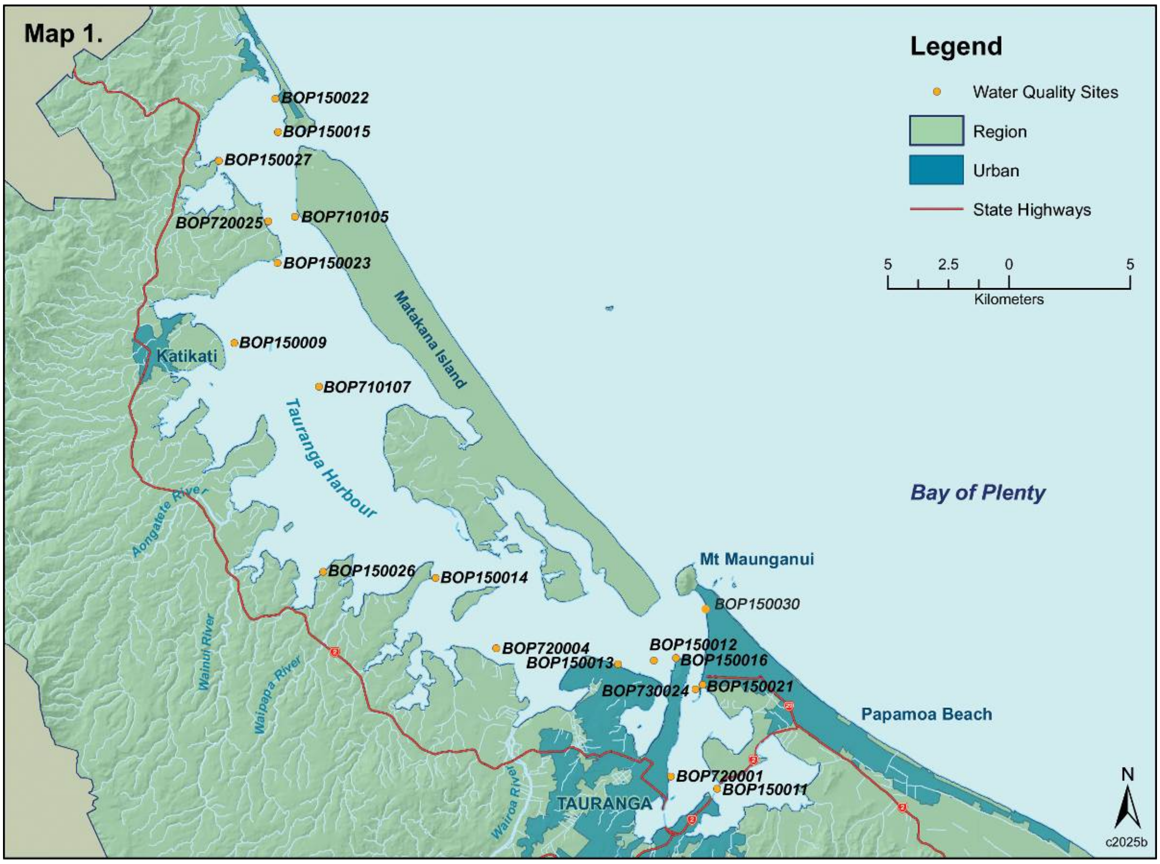


Figure 2.2 Estuary monitoring sites, Tauranga Harbour.

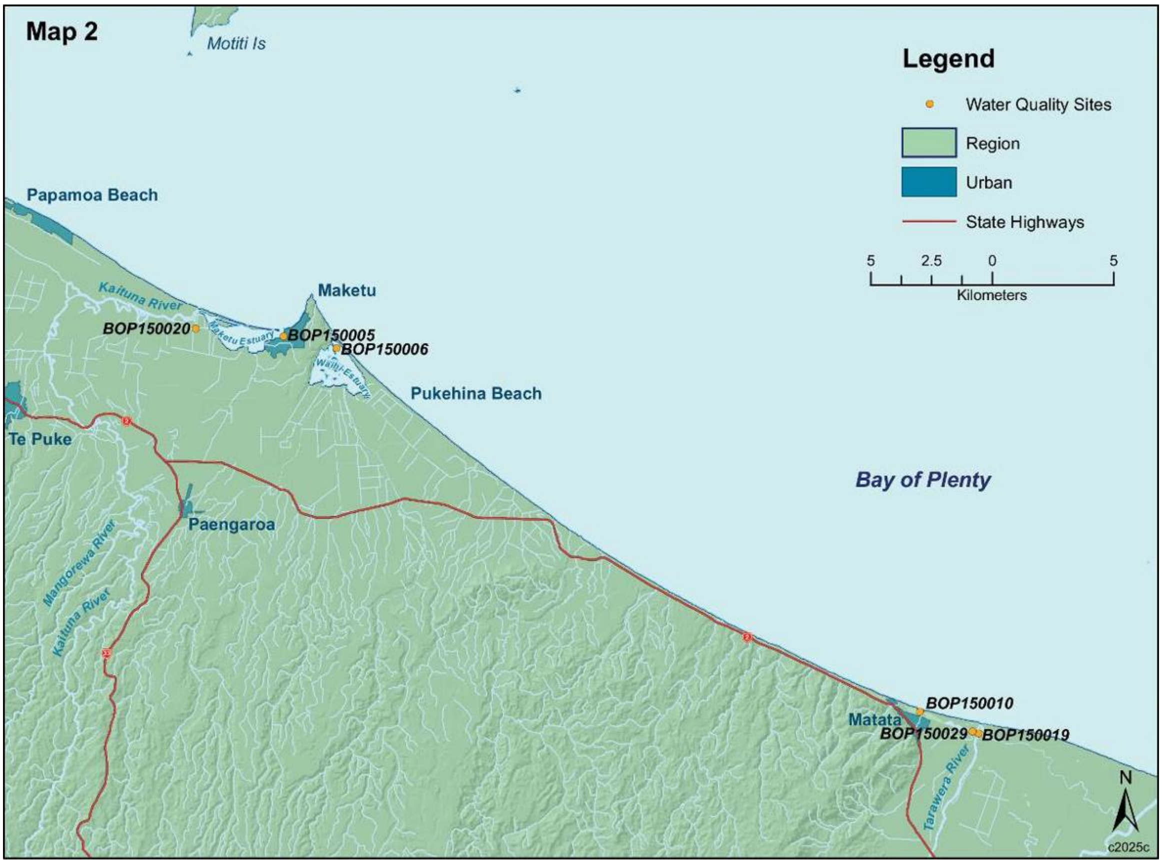


Figure 2.3 Estuary monitoring sites, Kaituna River to Tarawera River.

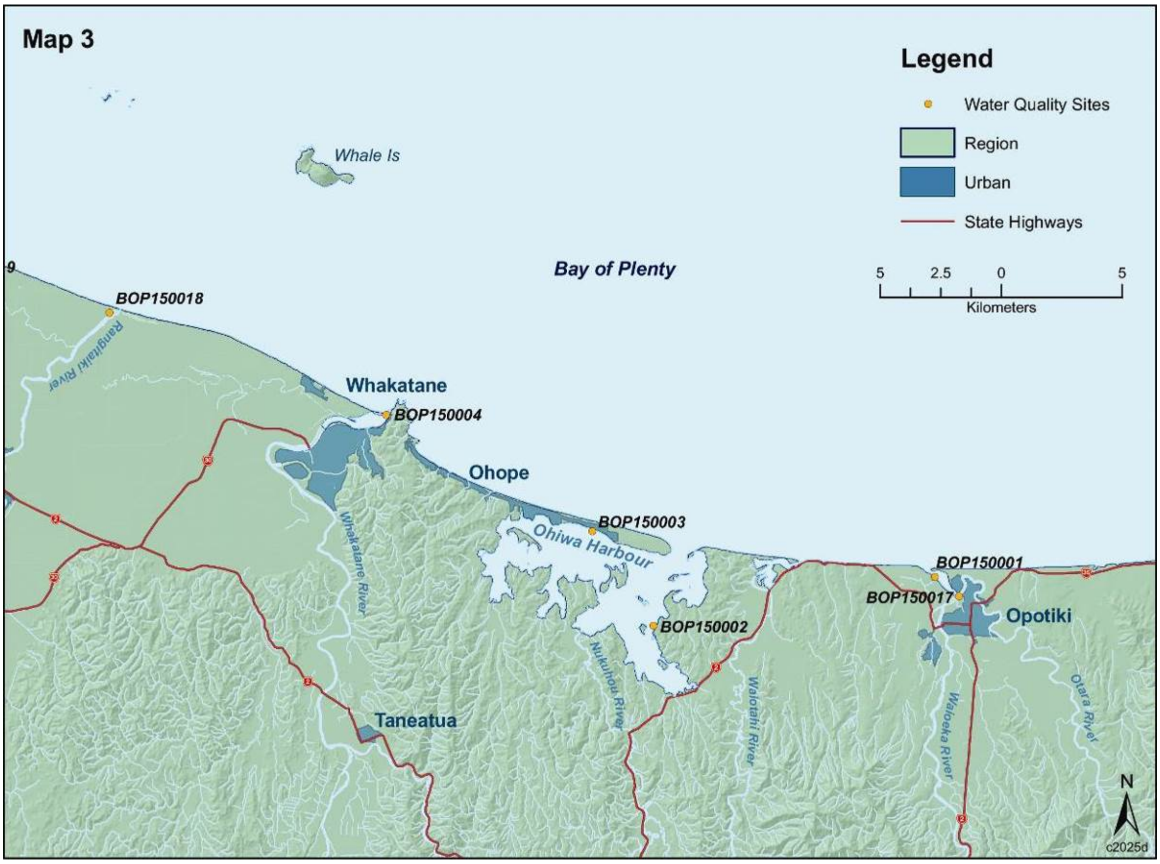


Figure 2.4 Estuary monitoring sites, Rangitāiki River to Ōpōtiki Estuary.

2.2 Sampling and analysis

Sampling was undertaken as per Bay of Plenty Regional Council internal protocols which follow standard best practice guidelines. Most analyses were performed by the Bay of Plenty Regional Council Laboratory, but for some periods analyses were undertaken by Hills Laboratory (Hamilton) and NIWA Laboratory (Hamilton). All chlorophyll-a analyses were performed by NIWA Laboratory (Hamilton).

Table 2.2 Methods used for chemical/biological analysis of water samples.

Parameter (abbreviation)	Method	Detection Limit/ Units
Ammonium Nitrogen (NH_4-N)	NWASCO Misc. Pub. No. 38, 1982. Phenolhypochlorite colorimetry.	1 mg/m^3
Total Oxidised Nitrogen (TOx-N)	Flow injection analyser, APHA 4500 NO3-I.	1 mg/m^3
Total Klejdahl Nitrogen[1] (TKN)	APHA Method 4500B NIWA mod., Oct 1990.	90 mg/m^3
Total Phosphorus (TP)	NWASCO Misc. Pub. No. 38, 1982. Acid persulphate digestion.	8 mg/m^3
Dissolved Reactive Phosphorus (DRP)	NWASCO Misc. Pub. No. 38, 1982. Antimony – phosphate – molybdate.	4 mg/m^3
Water clarity - black disc	Black disc measured in metres (to 0.1 m increments) with a viewing tube.	0.1 m
Turbidity	APHA Method 2130B-HACH 2100N ratio and signal averaging on.	0.01 NTU
pH	APHA method 4500-H+ measurement at 25^{o}C.	
Temperature	YSI or Hach DO Meter.	0.1 deg C
Conductivity	APHA Method 2510B, EDTRE 387 Tx Meter.	0.5 mS/m at 25 deg C
Suspended Solids (SS)	APHA Method 2540D.	0.5 g/m^3
Dissolved oxygen[2]	APHA Method 4500-0-G, YSI or Hach Meter.	0.5 g/m^3
Escherichia coli (E.coli) **Faecal coliform (FC)**	Membrane filtration, Standard Methods for the Examination of Water & Wastewaters (2005).	1 cfu/100 ml
Enterococci (Ent)	Method No 1600, USEPA 1986 EPA-821-R-97-004.	1 cfu/100 ml
Chlorophyll-a	1.0 um filtered. acetone pigment extraction, spectrofluorometric measurement.	0.1 mg/m^3

[1] Total nitrogen (TN) is derived from TKN and TOx-N if no TN analysis.
[2] Dissolved oxygen saturation (DO%) has been calculated using: DO% = (100 x DOg/m^3)/Cp (Cp = equilibrium oxygen at nonstandard pressure) when not measured directly.

2.3 Data assessment

Estuary water quality data sets have been assessed by temporal and comparative methods. Where available data allows, data sets have been assessed for trends using the methods described below. Changes to the frequency of sampling have occurred over the years leading to discontinuity in some data sets. The periods of data capture are listed in Appendix 1 of this report.

2.4 Trend analysis

Estuary water quality data sets have been assessed for trends using the methods described below.

Trend analysis has been undertaken on estuary sites with five or more years of data where the data offers reasonable continuity. Analysis is undertaken taking into account temporal and tidal changes where appropriate. The approach to trend analysis follows the non-parametric methods of Helsel and Hirsch (1992) which have been utilised by Vant and Smith (2004), and more recently have been used to analyse New Zealand's National River Water Quality Network (Ballantine and Davies-Colley, 2009).

To improve detection of trends in water quality data it is necessary to look at the influence seasonal variability and tidal variability has on the data. Seasonality affects many parameters such as temperature, or land use impacts on water quality may occur seasonally which in turn impact some water quality parameters. Likewise, tidal flow adjustment may be necessary as many water quality parameters will change with tidal influences. Monitoring of sites is timed to occur on the same tide, but this does not always happen. A change in tide and the mixture of fresh to saline waters can obscure underlying trends. To adjust for tidal influence conductivity as a measure of the change in the saline to freshwater environment has been used to help decrease variability and increase the power of trend detection.

Seasonality has been examined using the 'Time Trends' software[3] for each parameter at each site. If a seasonal pattern was identified then trend analysis was undertaken using the seasonal-Kendall test and if no seasonal pattern was readily identified then trend analysis was undertaken using the Mann-Kendall test.

Trend analysis involved computation of each parameter either with the seasonal-Kendall test or Mann-Kendall test using the Time Trends software. Tidal adjustment based on conductivity can be performed for each test where necessary and where this was done adjustment utilised Locally Weighted Scatterplot Smoothing (LOWESS) with a 30% span.

The Sen Slope Estimator (SEN) is used to represent the direction and magnitude of trends in data. This approach involves computing slopes for all the pairs of ordinal time points and then using the median of these slopes as an estimate of the overall slope.

Positive slopes indicate an increase in the values of a water quality parameter and negative slopes indicate an overall decrease. For each trend slope the probability of the slope occurring due to chance is also calculated. The *p*-value indicates if the trend detected is statistically significant. Conventionally, *p*-values of 5% (or $p<0.05$) or less are regarded as statistically significant (i.e. the 95% confidence level, unlikely to occur due to chance).

[3] http//www.niwa.co.nz/ncwr/tools

Results for trend analysis over the relative dataset record have been described firstly by their *p*-value (i.e. are they statistically significant) and then by their trend slope. The trend slope is expressed by the relevant parameters units/year. For many water quality variables when expressed in units/year the numbers are very small. Trend slopes in units/year have therefore been reformatted by multiplying by 10^{-3}, thus avoiding using a large number of zeros.

Values of the SEN were also normalised by dividing the raw data median to give the *relative* SEN (RSEN). Expressed as a percentage change per year (%/year), this standardisation of the slopes allows for easier comparison between sites (and parameters). *Meaningful* trends have been categorised by Scarsbrook (2006) and Ballantine and Davies-Colley (2009) as being those with RSEN greater than 1% per year with the null hypothesis for the Kendall test rejected ($p<0.05$).

2.5 Guidelines

Developing a picture of potential threats to estuarine water quality can be established by comparison of water quality parameters with water quality guideline values and between similar estuaries. This in part helps to meet the objectives of the RCEP and RWLP. Threats such as increasing sedimentation from urban development, erosion, and rural runoff, increased nutrients loads from intensive livestock farming, fertiliser runoff, and urban stormwater all have the potential to negatively impact on water quality. Algal blooms may occur as a direct result of increases in nitrogen and phosphorus. Reduced oxygen may result from excess ammonia and increased organic loading.

To help give a clearer picture as to the relevance of concentrations of a given parameter in the estuarine environment, this report makes use of the methods and trigger values for physical and chemical stressors for slightly disturbed ecosystems provided in the ANZECC Water Quality Guidelines (2000). Trigger values have been developed in these guidelines above which there is a greater risk that adverse conditions for biological organisms will occur. However, these trigger values may not represent a reliable or realistic measure of protection for Bay of Plenty waters as these values have been developed in different catchments with differing ecosystems. It is suggested that water quality managers develop their own physico-chemical indicators better suited to their respective regions.

There are no guideline values that have been developed specifically for New Zealand estuaries, so this assessment will at times refer to the trigger values developed for south-east Australian estuaries as well as trigger values for New Zealand lowland rivers. These guidelines do not necessarily provide a number at which environmental problems occur, but provide an indication of the level of environmental risk.

Trigger values are set out in Table 2.3.

Table 2.3 Trigger values for stressors for slightly disturbed estuarine ecosystems. (ANZECC, 2000)

	Chl a *mg/m³*	TP *mg/m³*	NOxN *mg/m³*	NH_4N *mg/m³*	Turbidity *NTU*
Trigger value estuaries	4	30	15	15	10*
Trigger value lowland rivers	-	33	444	21	5.6

*Adopted from Murphy and Crawford, 2002.

No value for suspended sediments or turbidity is given in the ANZECC guidelines for estuaries. However, as sediment is associated with re-suspension or input of nutrients, and can reduce light penetration, smother organisms and block fish gills, it is important to consider its concentration in the estuarine environment. A turbidity trigger value for New Zealand lowland rivers is given at 5.6 NTU. For Tasmanian estuaries an indicator value for turbidity greater than 10 NTU is considered high (Murphy and Crawford, 2002).

For indicator bacteria, the Microbiological Water Quality Guidelines (2003) are used for comparative purposes and to see if the qualitative standard for the classification has been met. The guidelines use enterococci for comparison in marine waters and *Escherichia coli (E.coli)* for freshwaters. Since both fresh and saline waters occur in some estuarine environments, it is appropriate to examine both indicator bacteria. Table 2.4 displays the guideline values as recommended by the Microbiological Water Quality Guidelines, 2003.

Table 2.4 Microbiological Assessment Category (MAC) definitions (from MfE and MoH, 2003).

Marine waters	
Green Mode	No single sample > 140 Enterococci per 100 mL
Orange Alert	Single sample > 140 Enterococci per 100 mL
Red Alert	Two consecutive samples > 280 Enterococci per 100 mL

Freshwater	
Green Mode	No single sample > 260 Escherichia coli per 100 mL
Orange Alert	Single sample > 260 Escherichia coli per 100 mL
Red Alert	Single sample > 550 Escherichia coli per 100 mL

Part 3: Trend results and other observations

3.1 Ōpōtiki River Estuary

The Ōpōtiki Estuary is a relatively small riverine estuary (0.5 km^2) joining with the confluence of the Waioeka and Otara Rivers to provide a common mouth for these rivers. The lower catchment for this estuary is dominated by intensive livestock farming.

3.1.1 Ōpōtiki River Estuary trends

Analysis has shown a few trends for several parameters at both sites, Ōpōtiki Wharf having the shorter period of available data. A significant increasing trend in pH is exhibited at the wharf site over 1995 to 2013, a trend that is not seen in the Kukumoa data. Both sites show a meaningful decreasing trend in ammonia (Figures 3.2 and 3.4), possibly due to improvements in agricultural waste discharges in the early 1990s. This is in part backed up by the small but statistically significant decreasing trend of faecal coliforms at Kukumoa (Figure 3.5), another potential indicator of improvements in agricultural industrial discharges.

Table 3.1 Trend statistics for Ōpōtiki Wharf.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Ōpōtiki Wharf	***Trend***	□	□	⬀	□	□	□
	%/yr (RSEN)	0.7	<0.01	**0.19**	-0.4	0.78	0.21
	Slope (10^{-3} units/yr)	18.2	<0.01	**13.5**	-7.7	7.9	4.4

Site		DRP (g/m^3)	NH$_4$-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Ōpōtiki Wharf	***Trend***	➚	➘	□	□	□	□
	%/yr (RSEN)	**1.6**	**-2.37**	1.06	-0.37	1.27	4.14
	Slope (10^{-3} units/yr)	**0.23**	**-0.4**	0.7	-0.6	0.4	3.4

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis periods given in table A.1).

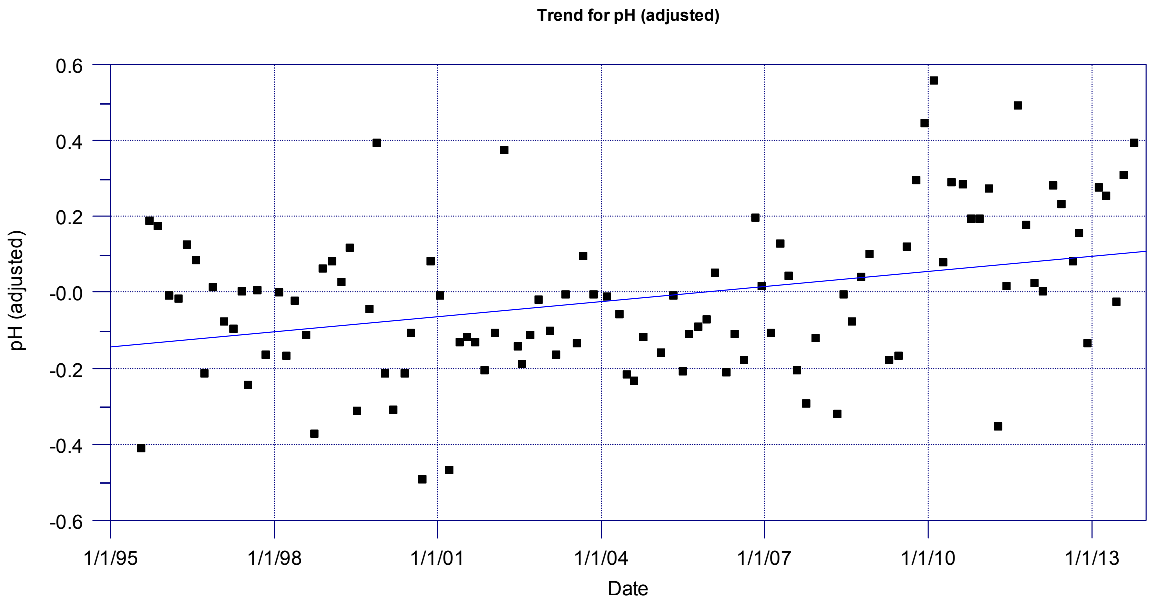


Figure 3.1 Sen slope trend for pH, Wharf, Ōpōtiki estuary.

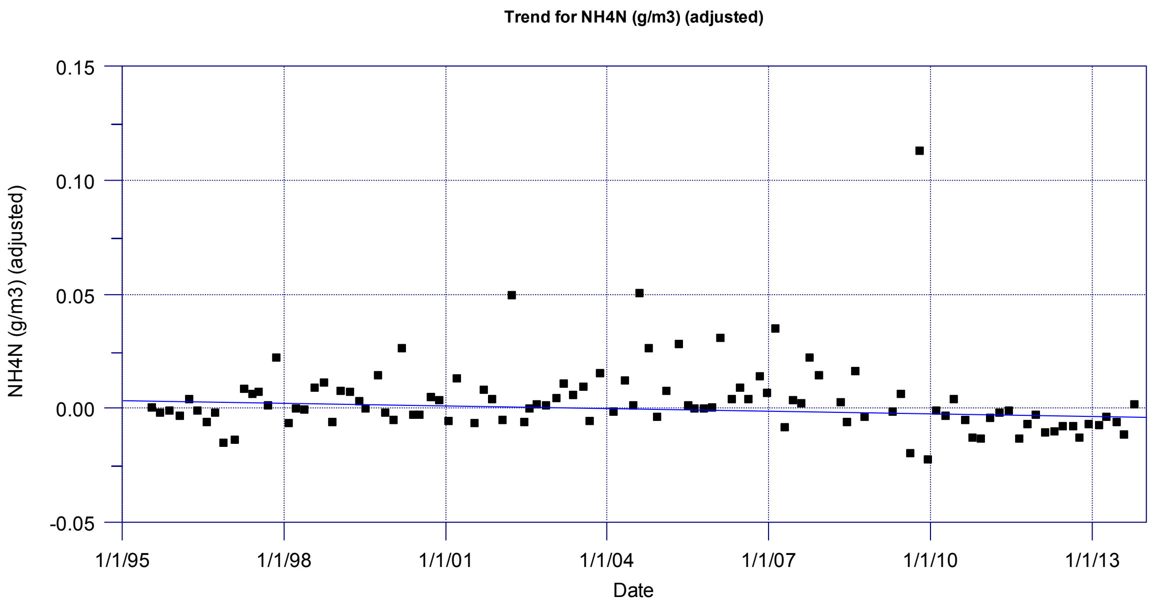


Figure 3.2 Sen slope trend for NH_4-N, Wharf, Ōpōtiki Estuary.

Table 3.2 Trend statistics for Ōpōtiki at Kukumoa.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Ōpōtiki Kukumoa	***Trend***	▫	▫	▫	▫	▫	⬂
	%/yr (RSEN)	3.6	-4.7	-0.02	-0.6	0.3	**-0.6**
	Slope (10^{-3} units/yr)	147	-128	-1.8	-10.8	3.7	**-13.8**

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Ōpōtiki Kukumoa	***Trend***	⬈	⬊	▫	▫	▫	⬈
	%/yr (RSEN)	**1.2**	**-3.0**	1.9	-3.5	<0.01	**3.0**
	Slope (10^{-3} units/yr)	**0.6**	**-0.6**	0.5	-7.1	<0.01	**6.5**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ⬈⬊ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis periods given in table A.2).

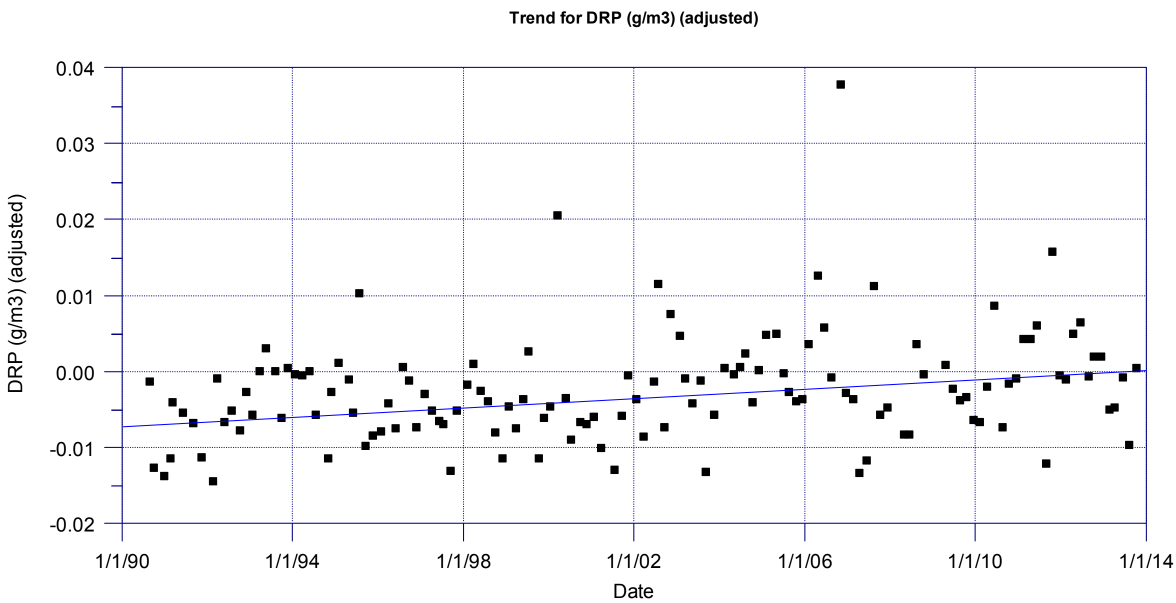


Figure 3.3 Sen slope trend for DRP, Kukumoa, Ōpōtiki estuary.

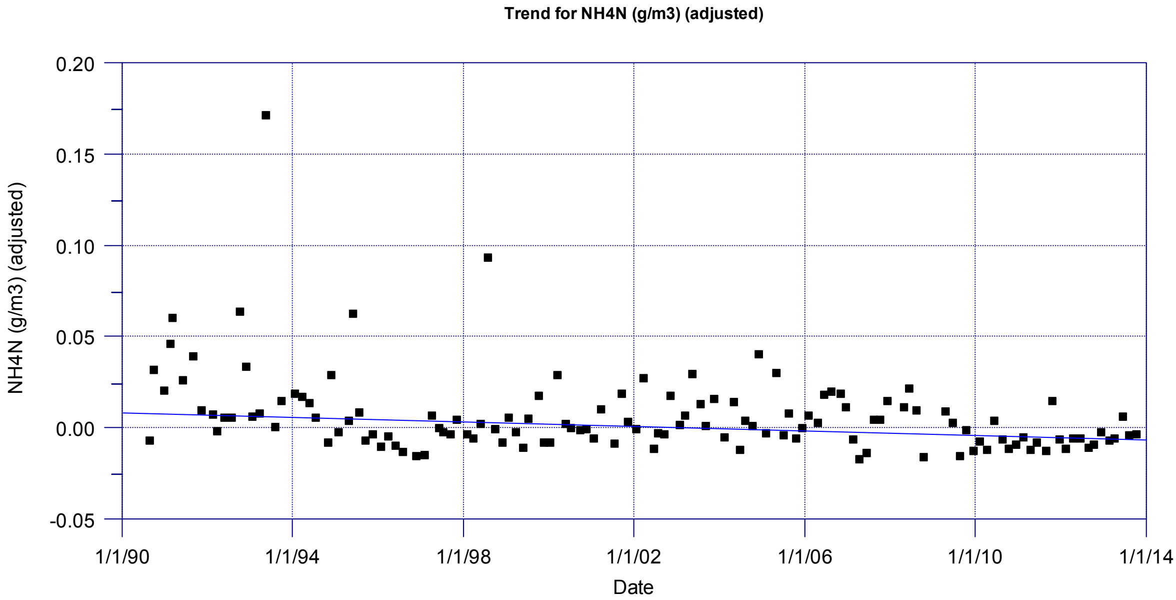


Figure 3.4 Sen slope trend for NH_4-N, Kukumoa, Ōpōtiki estuary.

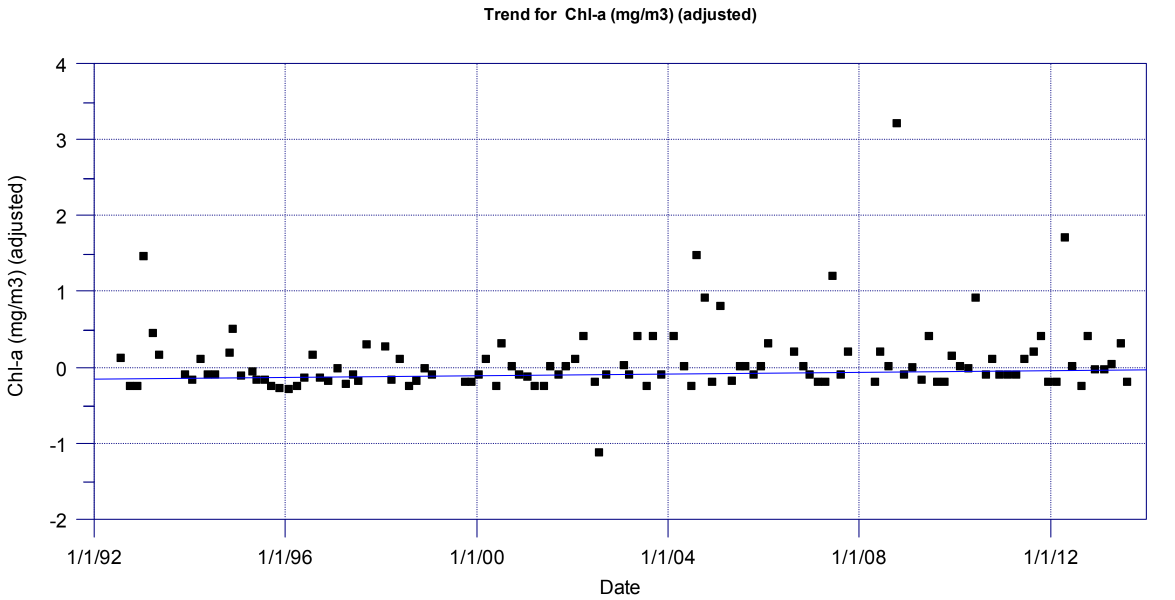


Figure 3.5 Sen slope trend for Chlorophyll-a, Kukumoa, Ōpōtiki estuary.

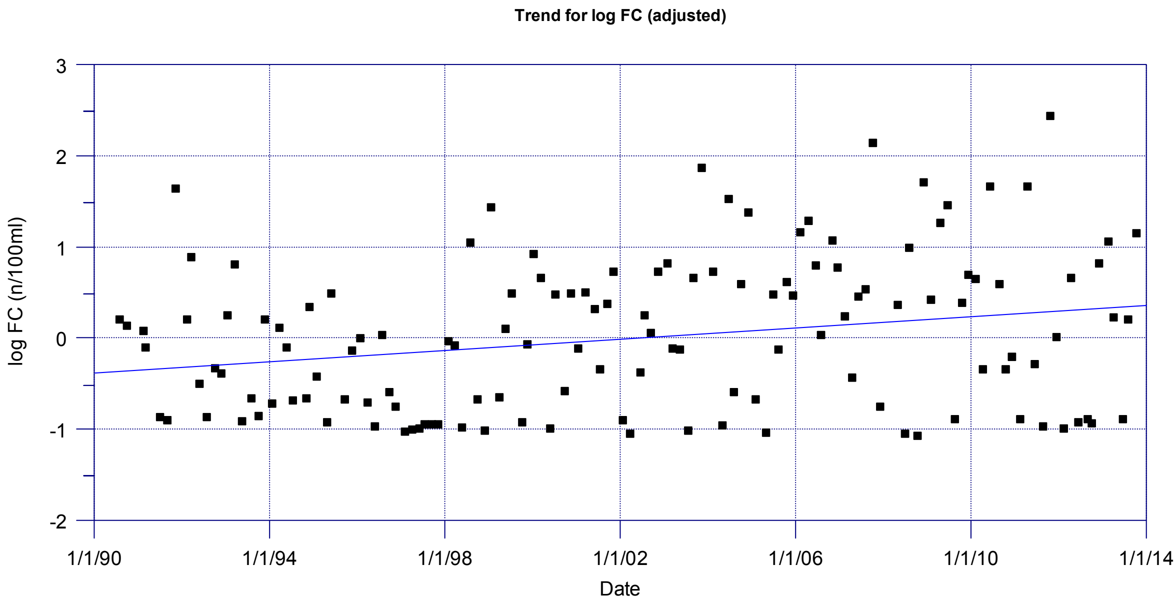


Figure 3.6 Sen slope trend for log10 faecal coliforms, Kukumoa, Ōpōtiki estuary.

Like the Wharf site, dissolved reactive phosphorus (DRP) has a meaningful increasing trend at Kukumoa (Figure 3.4). Kukumoa has a higher mean DRP concentration than the Wharf site (see Appendix 1), and both sites have a negative correlation of DRP with salinity (Pearson R=-0.56 and -0.67, $p<0.01$) which indicates the predominant source of DRP is with increasing freshwater flows.

Chlorophyll-a has a meaningful increasing trend at Kukumoa, showing increased phytoplankton productivity in the estuary. This could be linked to increasing DRP however no obvious relationship between these parameters is apparent.

3.2 Ōhiwa Harbour

Ōhiwa Harbour covers an area of approximately 26.4 km^2 and is shallow with 83% of its area exposed at low tide. The estuary is enclosed by Ohope and Ōhiwa spits and is rapidly changing with coastal and catchment sediment contributing to infilling of the estuary.

Fresh water inflows to the estuary are dominated by the Nukuhou River which drains part of the 171 km^2 Ōhiwa Catchment. Pastoral farming dominates the land use in the catchment followed by indigenous and production forest. Urban areas are restricted to the northern end of the estuary predominantly on the Ohope side.

Monitoring takes place at two sites in the estuary, one at Port Ohope Wharf and the other at Ruatuna Road (Figure 1.4). Sites are geographically distinct from one another, with the Port site representative of the harbours western side. The Ruatuna Road site represents the eastern side of the harbour which has the Kutarere and Te Kahaha streams flowing into its southern extent. There is limited freshwater influence at the two monitoring sites, which is demonstrated by the conductivity levels in Tables A.3 and A.4, particularly as samples are taken at high tide. Other monitoring statistics can also be viewed in Appendix 1, Tables A.3 and A.4.

3.2.1 Ōhiwa Estuary trends

Several trends are apparent at the Ōhiwa Harbour sites (Tables 3.3, 3.4 and Figures 3.7 to 3.11). The Port Ōhope site shows a significant increasing trend in suspended solids (SS) concentrations (Figure 3.7). SS concentrations have lessened in the past few years and the increasing trend may be a result of intense rainfall events delivering larger amounts of sediment to estuary over the 2004 to 2010 period.

Table 3.3 Trend statistics for Ruatuna Road.

Site		SS (g/m^3)	Turbidity (NTU)	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Ruatuna	***Trend***	□	□	↗	↗	↗
	%/yr (RSEN)	1.67	-1.57	6.5	16.3	5.31
	Slope (10^{-3} units/yr)	204	-63.9	19.8	33.6	34.2

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Ruatuna	***Trend***	□	□	□	□	↘	□
	%/yr (RSEN)	0	0.68	13.3	2.88	-0.95	0.3
	Slope (10^{-3} units/yr)	0	0.1	0.2	5.7	-0. 2	1.7

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ↗↘ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis period given in table A.3).

Table 3.4 Water quality statistics for Port Ohope.

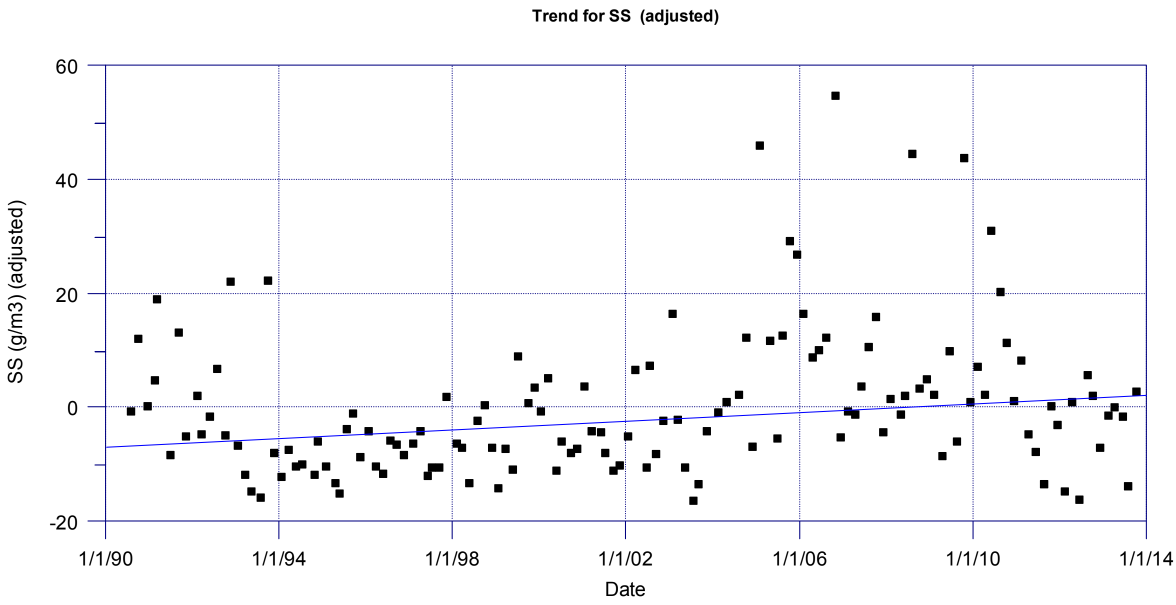
Site		SS (g/m^3)	Turbidity (NTU)	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Port Ohope	***Trend***	↗	□	□	□	□
	%/yr (RSEN)	**2.7**	-0.3	1.3	15.0	2.4
	Slope (10^{-3} units/yr)	394	-12.2	2	11.7	7

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Port Ohope	***Trend***	□	□	□	□	□	□
	%/yr (RSEN)	-1.6	<0.01	<0.01	3.45	-0.9	0.1
	Slope (10^{-3} units/yr)	-0.1	<0.01	<0.01	7.1	-0.2	0.9

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ⬈⬊ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis periods given in table A.4).

Total phosphorus (TP) has a meaningful and significant decreasing trend at the Ruatuna Road site (Figure 3.9). It may be in some way be explained by elevated chlorophyll-a concentrations in the mid-1990s, which could have increased water column TP at the time. Decreasing application of phosphorus based fertilisers may also explain this trend.

The faecal indicator bacteria, *E.coli,* faecal coliforms (FC) and enterococci (Ent) also show increasing trends (Figures 3.10 and 3.11*)*. *E.coli* have been showing an increase in the order of 6.5% per annum in the eastern estuary. The indicator bacteria enterococci displays a similar pattern of variation at both sites, although only Ruatuna Road has a significant trend. In saline waters this indicator is used to gauge the risk to contact recreational users and it has rarely been at levels that would be deemed unsafe for



contact recreational use.

Figure 3.7 Sen slope trend for SS, Port Ōhope, Ōhiwa Estuary.

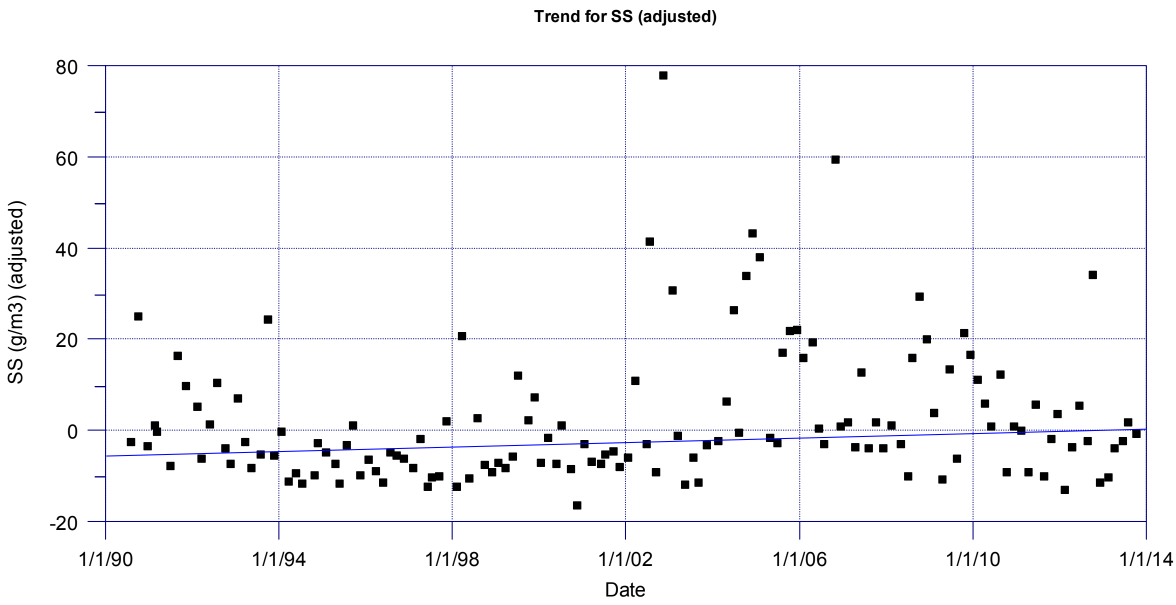


Figure 3.8 Sen slope trend for SS, Ruatuna Road, Ōhiwa Estuary.

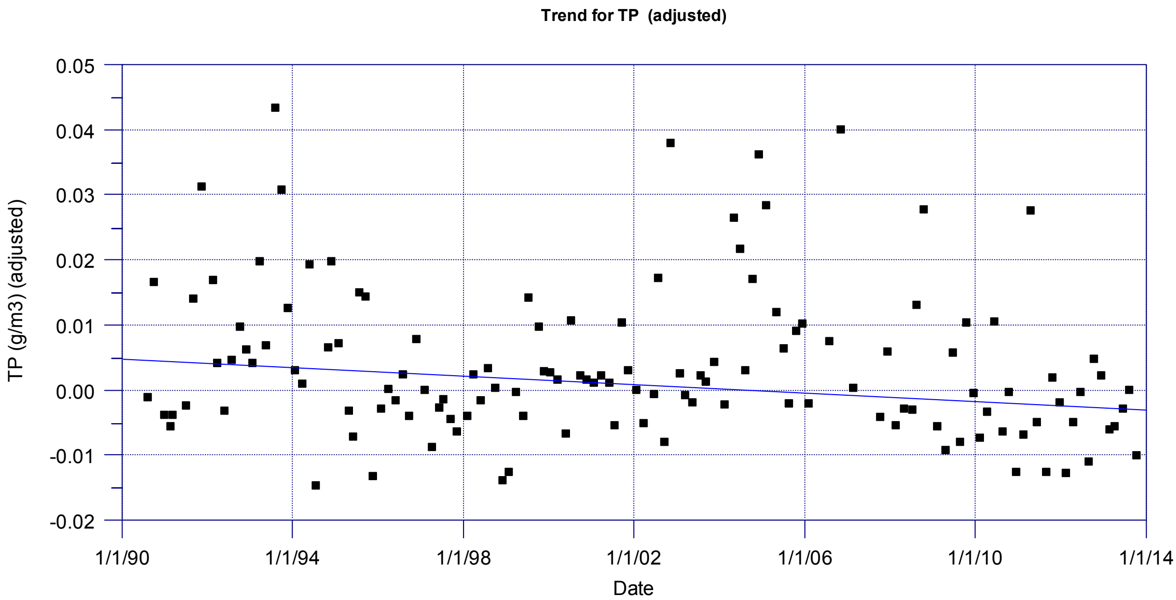


Figure 3.9 Sen slope trend for TP, Ruatuna Road, Ōhiwa Estuary.

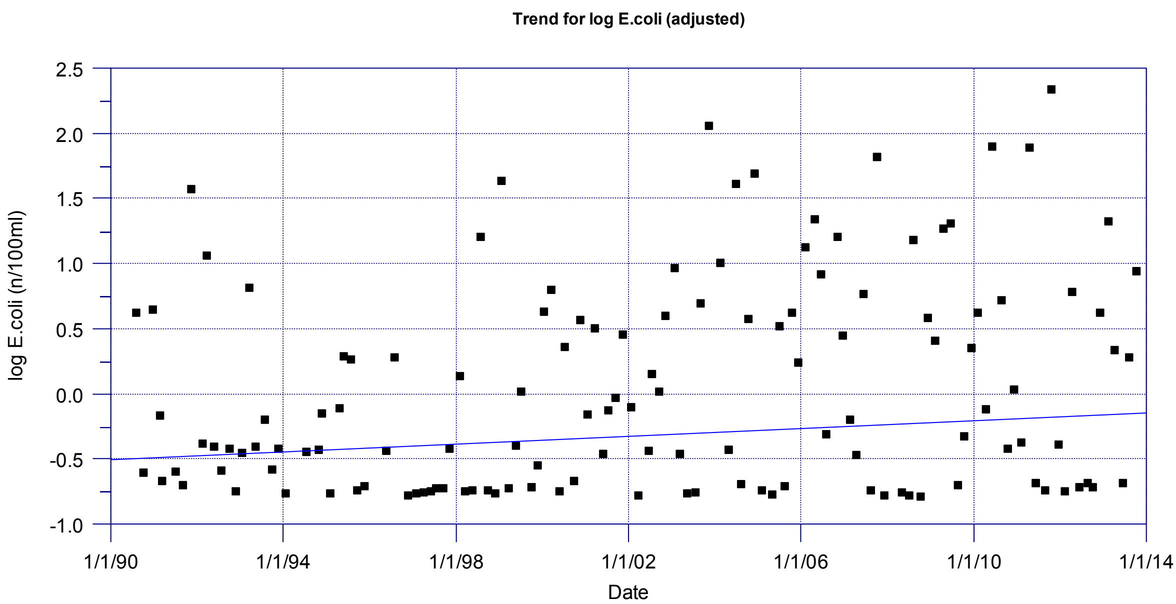


Figure 3.10 Sen slope trend for log10 E.coli, Ruatuna Road, Ōhiwa Estuary.

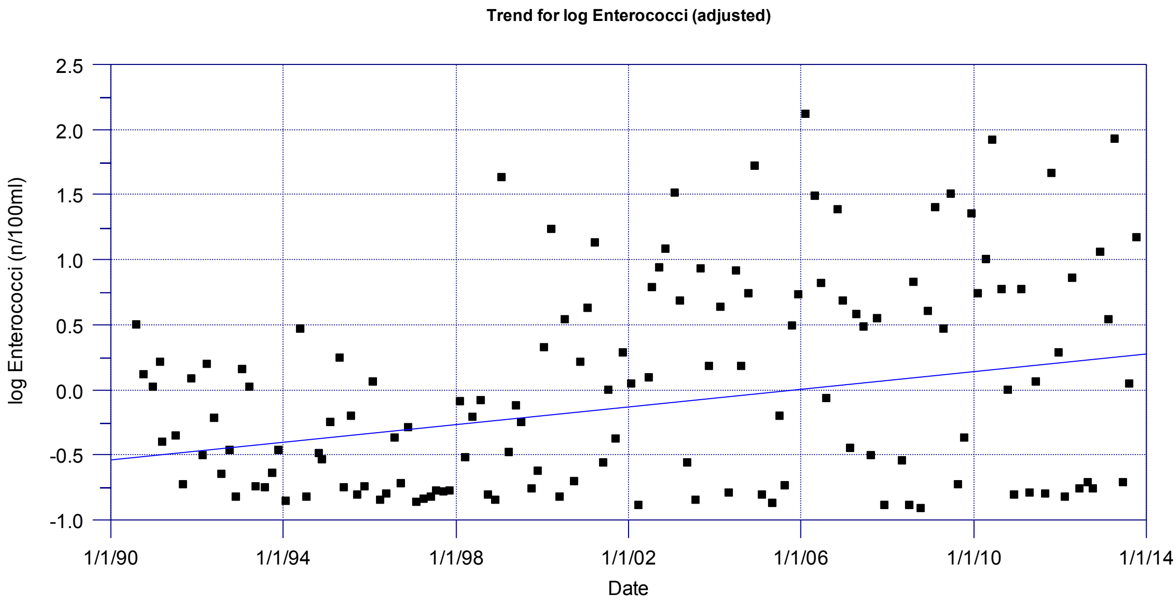


Figure 3.11 Sen slope trend for log10 Enterococci, Ruatuna Road, Ōhiwa Estuary.

The suspended solids trends are influenced by high sediment loads generated during several intense storm events post 2004. Increased sedimentation is the greatest risk posed to rivers, streams, and eventually the estuary. Suspended solids can come from storms eroding vulnerable hill country, or from activities such as earthworks. Sedimentation will have detrimental impacts on habitat values due to smothering of fauna, decreased water clarity, increased nutrient loading, and potentially changes to habitat zones. Increased mangrove spread in the harbour may be a result of increased mud content of the sediment in certain areas of the harbour (MacKenzie, 2013).

The increases in the faecal indicator bacteria also suggest an increasing influence of land use, predominantly pastoral agriculture on the eastern side of the estuary. While average faecal indicator bacteria levels are well below contact recreation guidelines, maximum faecal indicator bacteria levels can be above these guidelines at times.

3.3 Whakatāne River Estuary

The highly modified Whakatāne Estuary is approximately 1.3 km^2 in size and is largely influenced by the freshwater flow from the Whakatāne River. The catchment (1,768 km^2) is predominantly in native and exotic forest with intensive livestock agriculture dominating the lowlands.

The Whakatāne Boat Ramp is currently the monitoring site for the estuary although some monitoring has occurred at Quay Street and adjacent to the Yacht Club.

Water quality statistics are given in Table A.5 (Appendix 1).

3.3.1 Whakatāne River Estuary trends

Turbidity shows a significant decreasing trend (Figure 3.12) indicating some improvement in water clarity over the past decade. DRP is also decreasing in the estuary (Figure 3.13), although TP shows no significant trend. DRP and turbidity do show a strong correlation with each other (Pearson R=0.708, $p<0.01$). Both these parameters, like many other parameters in the estuary, are negatively correlated with salinity, indicating the dominant catchment influence on these parameters.

Table 3.5 Water quality statistics for Whakatāne River Estuary.

Site		SS (g/m^3)	Turbidity (NTU)	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Whakatāne	***Trend***	▫	⬂	▫	▫	▫
	%/yr (RSEN)	-0.02	-0.2	0.9	0.28	0.88
	Slope (10^{-3} units/yr)	-1.7	-15	12	6	4

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Whakatāne	***Trend***	⬊	▫	▫	▫	▫	▫
	%/yr (RSEN)	**-1.80**	2.01	0.91	-1.8	3.72	1.54
	Slope (10^{-3} units/yr)	<1	3	1	-4.8	2680	6.4

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ⬈⬊ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis periods given in table A.5).

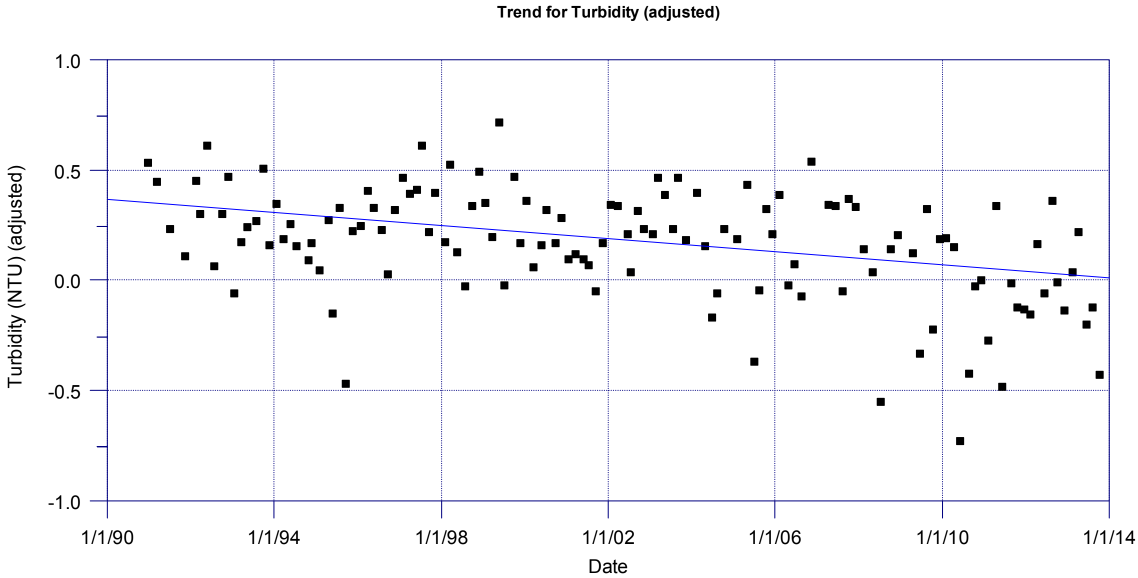


Figure 3.12 Sen slope trends for turbidity, Whakatāne River Estuary.

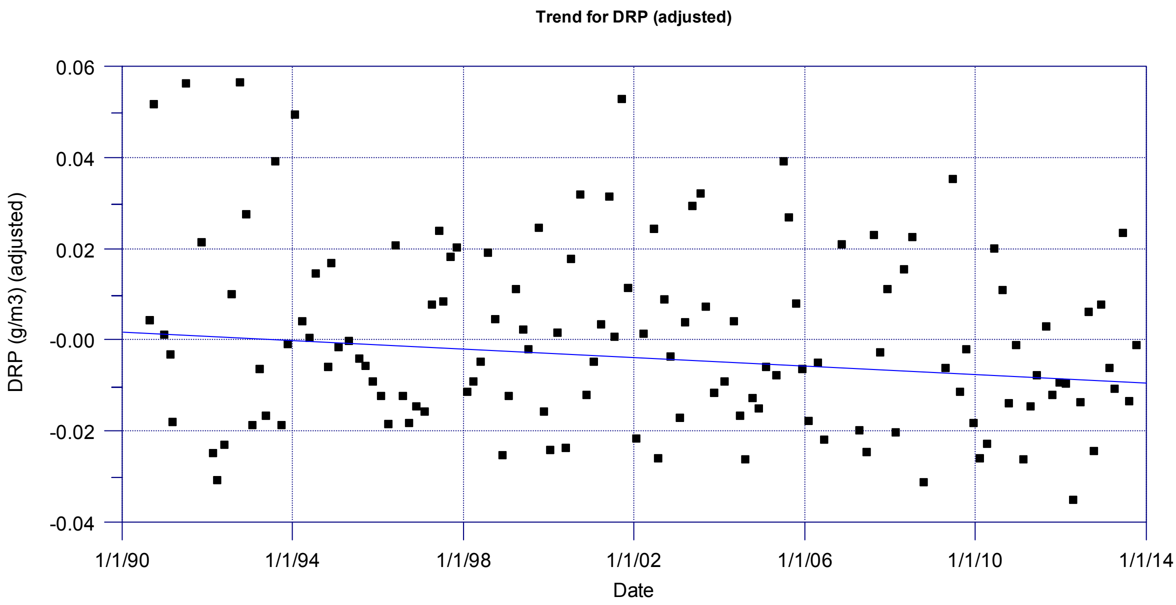


Figure 3.13 Sen slope trends for DRP, Whakatāne River Estuary.

3.4 Rangitāiki River Estuary

Like the Whakatāne Estuary, the small Rangitāiki Estuary is influenced by a large continuous fresh water input and is a popular recreational area for fishing and boating.

The Rangitāiki catchment is approximately 3,005 km^2 ranging from the native forest dominated Te Urewera National Park to the Rangitāiki coastal plains. Two power schemes form dams in the river system, one at Lake Aniwhenua and the other being Matahina Dam. The Galatea and Rangitāiki plains are dominated by dairy farming with other pastoral farming supporting sheep, drystock and deer. Cropping and horticulture are also scattered over the plains with exotic forestry the primary land use on surrounding hill country as far back as Te Urewera National Park. The townships of Te Teko and Edgecumbe are located on the lower reaches of the Rangitāiki and at Edgecumbe the Fonterra Dairy Factory is a significant user of river water and discharges process waste water to the river.

The monitoring station is at the jetty adjacent to the boat ramp. Water quality monitoring statistics are given in Appendix 1, Table A.6.

3.4.1 Rangitāiki River Estuary trends

Three (meaningful) significant trends were detected in the data from 1995 to 2013. Increasing TOx-N (Table 3.6, Figure 3.15) is consistent with what is observed at some upstream sites, however no increase in productivity in the estuary has been observed in the indicator chlorophyll-a. Chlorophyll-a does display a strong seasonality in the estuary (Figure 3.17) and is most strongly correlated with temperature (Pearson $r=0.711$, $p<0.01$), which is likely to be the biggest driver of phytoplankton productivity in the water column. An increasing trend in phosphorous, dissolved (Figure 3.14) and total (Figure 3.16), were also observed. There is no correlation of phosphorus concentrations to chlorophyll-a, but DRP does show a similar seasonal pattern to five-day average lactose concentrations as monitored for the Edgecumbe dairy factory discharge.

Table 3.6 Trend statistics for Rangitāiki River Estuary.

Site		SS (g/m^3)	Turbidity (NTU)	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Rangitāiki	***Trend***	▫	▫	▫	▫	▫
	%/yr (RSEN)	0.49	-0.79	-0.17	-0.7	-0.67
	Slope (10^{-3} units/yr)	14.9	-15.8	-3.4	-12.2	1.5

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Rangitāiki	***Trend***	➚	▫	➚	▫	➚	▫
	%/yr (RSEN)	**2.25**	<0.01	**3.45**	2.1	**1.60**	-0.71
	Slope (10^{-3} units/yr)	**1**	<0.01	**13**	12.3	**0.9**	2.5

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis periods given in table A.6).

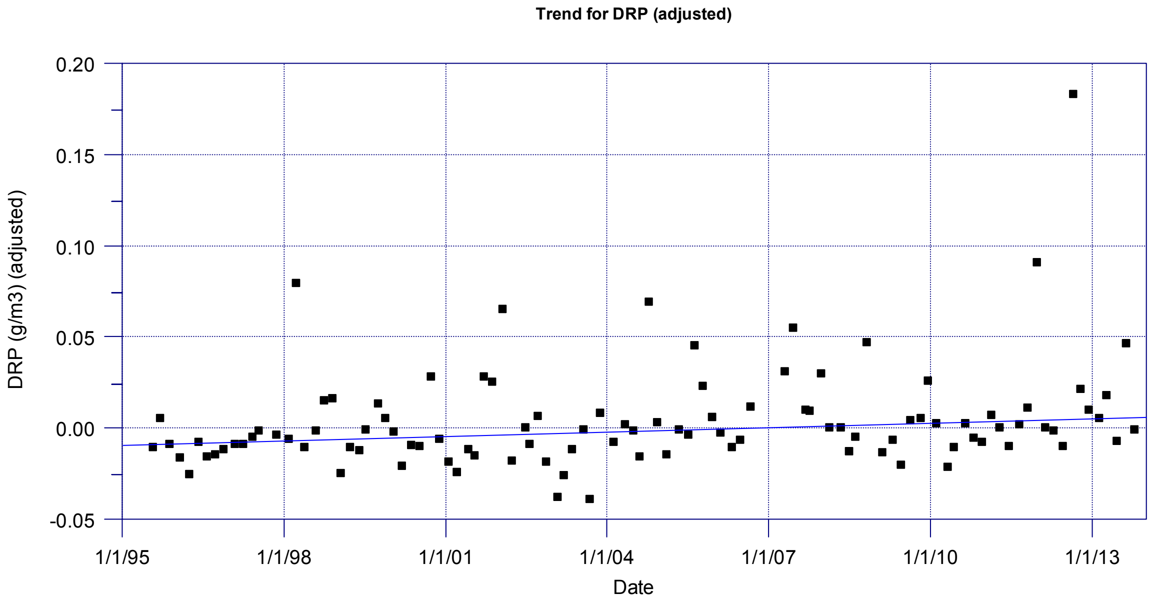


Figure 3.14 Sen slope trend for DRP, Rangitāiki River Estuary.

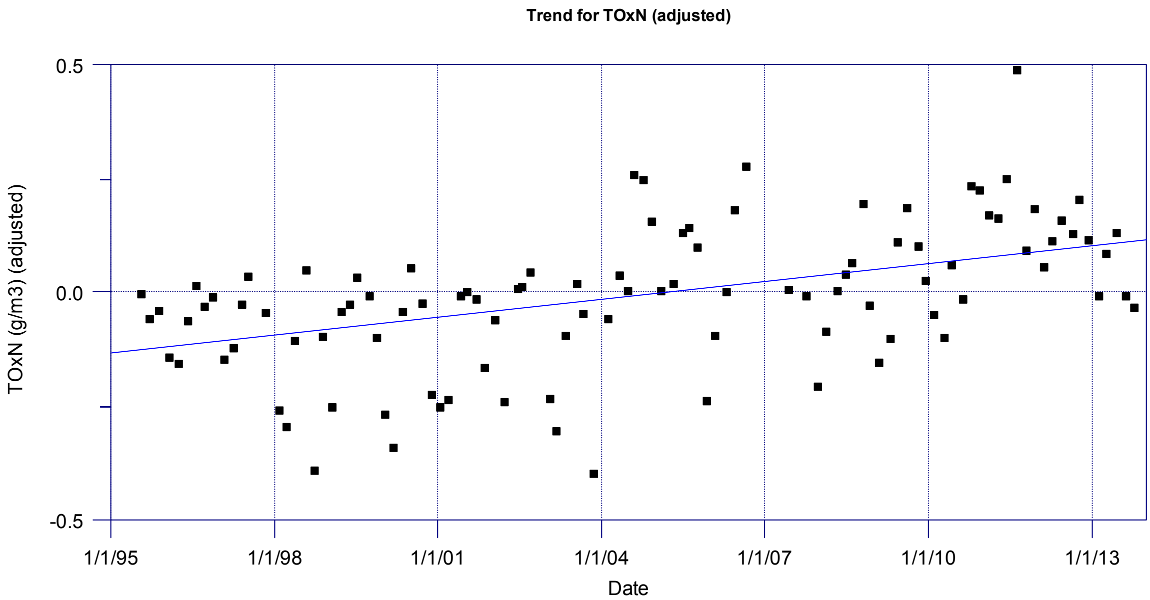


Figure 3.15 Sen slope trend for TOx-N, Rangitāiki River Estuary.

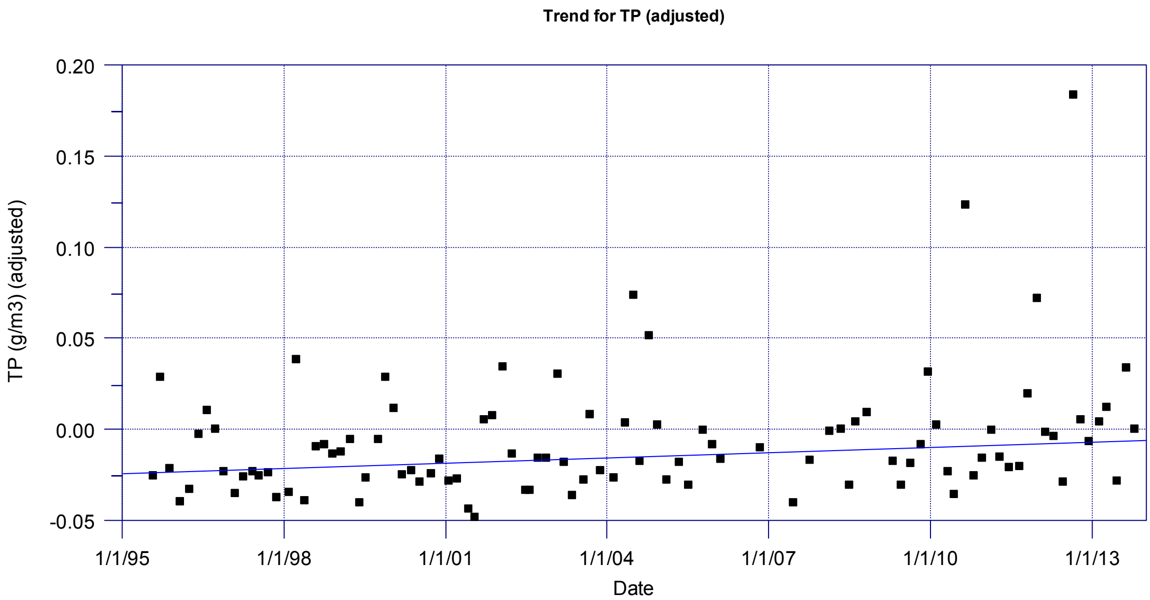


Figure 3.16 Sen slope trend for TP, Rangitāiki River Estuary.

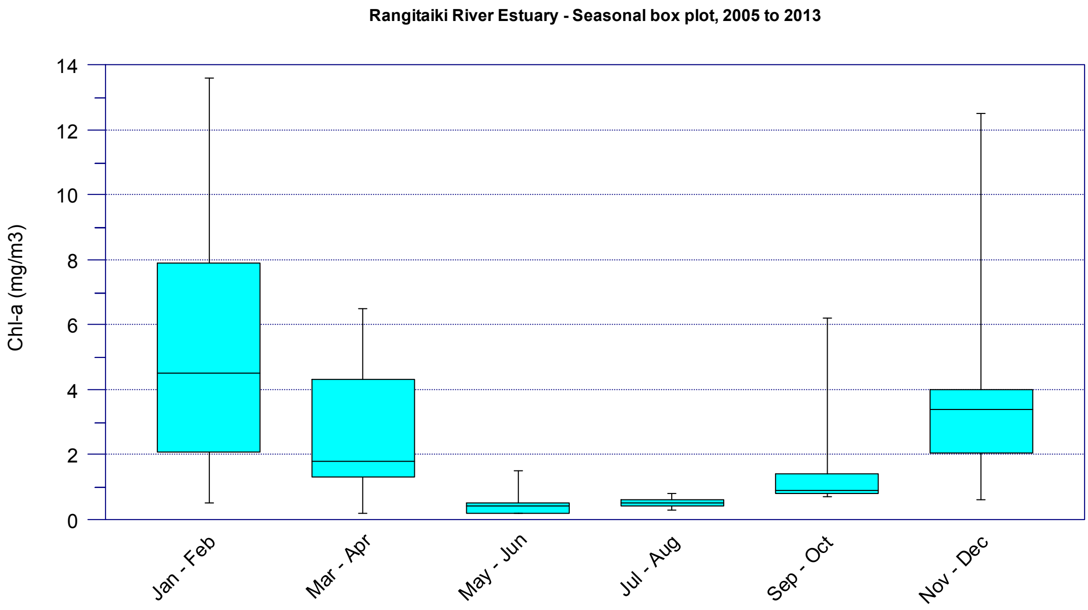


Figure 3.17 Box-whisker plot of chorophyll-a, Rangitāiki River Estuary, (median, upper and lower quartiles, maximum and minimum are displayed).

3.5 Tarawera River Estuary

The Tarawera River Estuary is a small estuary of approximately 0.72 km^2 with a catchment of approximately 984 km^2 in size extending from the Okataina Volcanic Centre. The upper catchment is a mixture of indigenous forest, pasture and exotic forestry and scrub. The lower catchment contains the township of Kawerau and the Tasman industrial complex, which processes wood based products and is a large user of Tarawera River water. This complex discharges water used in industrial processes back to the river after treatment. Kawerau sewage is also processed through rapid infiltration basins located in the Tasman industrial complex. Stormwater and treated sewage from the Edgecumbe township also flow into the river by way of the Omeheu/Awaiti canal system. The plains of the lower catchment are dominated by intensive dairying with some horticulture and cropping.

Monitoring is undertaken 50 m downstream of the Thornton Road bridge. Water Quality statistics are in Table A.7, Appendix 1.

3.5.1 Tarawera River Estuary trends

E.coli, faecal coliforms, NH_4-N, SS and turbidity all show (meaningful) significant decreasing trends in the data from 1995 to 2013 (Table 3.7, Figure 3.18-3.21). This may be a result of improvements in Tasman Mill and Kawerau waste water discharges.

Like the Rangitāiki River Estuary, TOx-N has a meaningful increasing trend (Table 3.7, Figure 3.20) and has a strong seasonal pattern with winter maximums and summer minimums. TOx-N concentrations remain well below nitrate toxicity guidelines for environments which are subject to a range of disturbances from human activities.

Table 3.7 Trend statistics for Tarawera River Estuary.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Tarawera	***Trend***	↘	↘	□	↘	□	↘
	%/yr (RSEN)	**-2.99**	**-4.27**	0.02	**-2.16**	-0.3	**-1.46**
	Slope (10^{-3} units/yr)	**-256**	**-242**	1.5	**-54**	-2.6	**-41**

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Tarawera	***Trend***	□	↘	↗	□	□
	%/yr (RSEN)	0.67	**-1.55**	**2.21**	-0.1	-0.02
	Slope (10^{-3} units/yr)	0.5	**-0.7**	**9**	-0.1	-0.1

Trend: ⇗⇘ significant increasing or decreasing trend of parameter over time ($p<0.05$); ↗↘ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis period given in Appendix A.7).

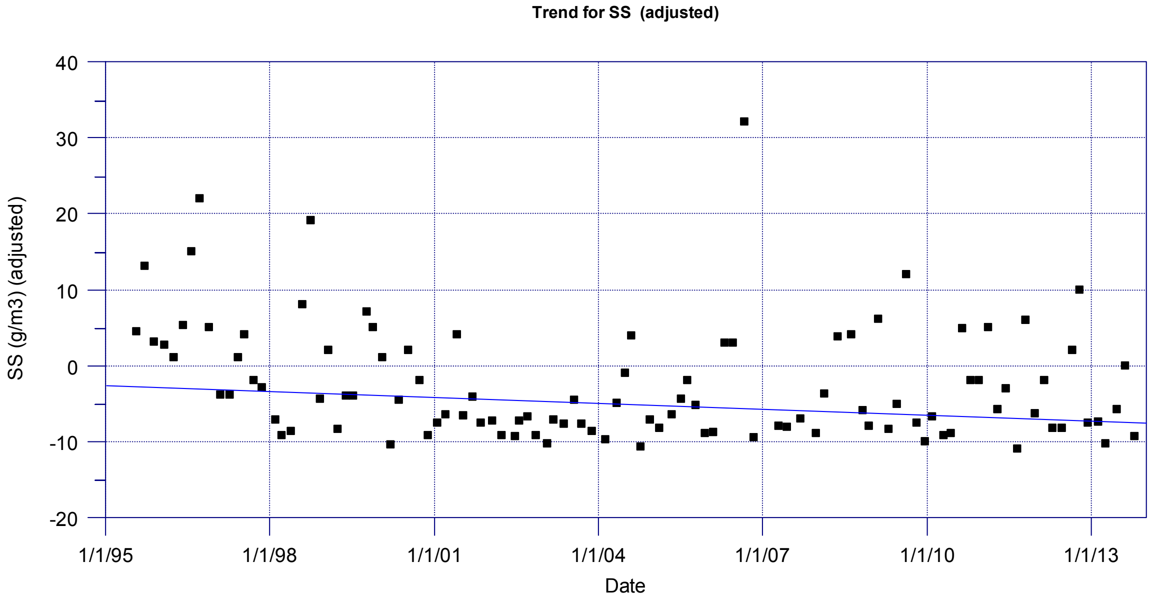


Figure 3.18 Sen slope trend for SS, Tarawera River Estuary.

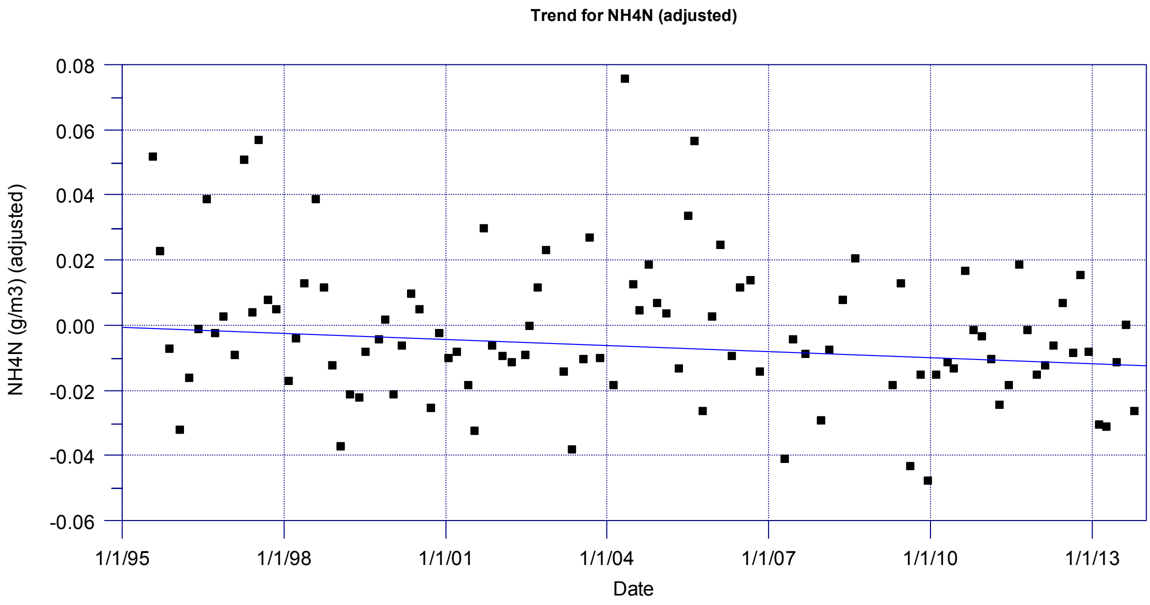


Figure 3.19 Sen slope trend for NH_4-N, Tarawera River Estuary.

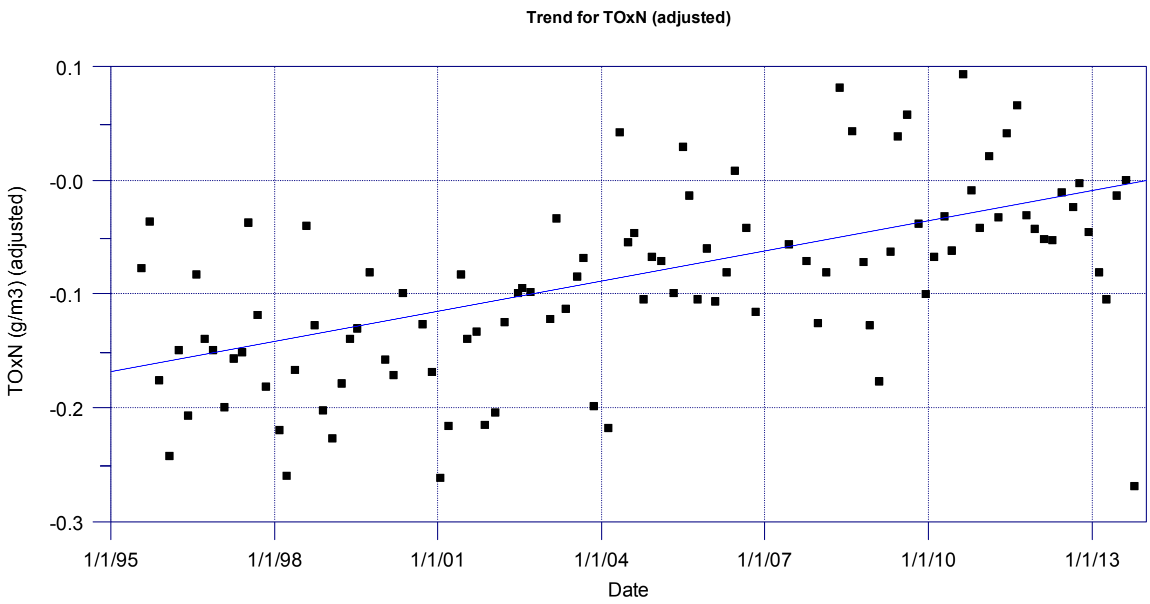


Figure 3.20 Sen slope trend for TOx-N, Tarawera River Estuary.

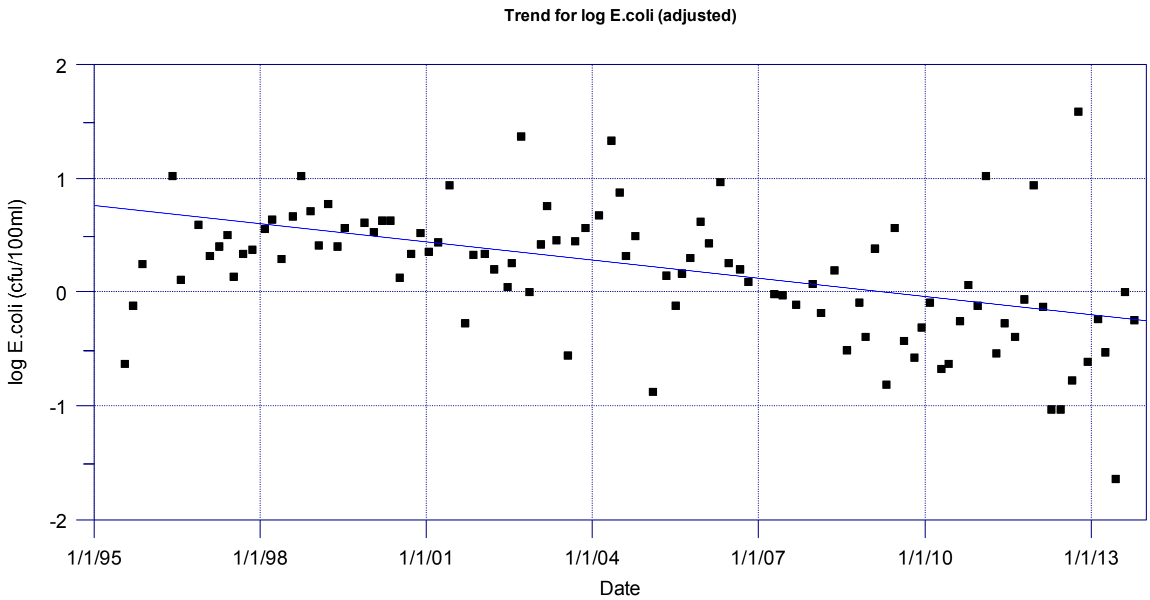


Figure 3.21 Sen slope trend for log10 E.coli, Tarawera River Estuary.

3.6 Waihi Estuary

The 2.4 km^2 shallow tidal inlet that forms Waihi Estuary is impounded by a long spit upon which the Pukehina community has settled. Much of the estuary dries at low tide with the main channel providing the conduit of water to a few narrower channels.

The estuary is fed freshwater from a number of stream fed drainage canals. These waters pass through a catchment (32,819 ha) of exotic and native forests in the headwaters to mixed horticulture, sheep, beef farms and dairy farms on the rolling hill country and plains. Drains tend to provide a high level of nutrients and bacteria to the estuary and there has been a history of septic tank contamination from the local Little Waihi community. Reticulation occurred for this community in 2012 but Pukehina remains un-reticulated.

Monitoring occurs in the main channel opposite the Little Waihī campground. Water quality statistics for the estuary are tabulated in Appendix 1, Table A.8.

3.6.1 Waihi Estuary trends

Several meaningful significant trends are seen in the data from Waihī Estuary (Table 3.8).

All faecal indicator species show a meaningful significant increasing trend over the period 1990 to 2014 (Figure 3.22 and 3.23). The Pongakawa Stream, the largest freshwater inflow to the estuary shows little change to indicator bacterial levels over the past 15 years (as measured at State Highway 2), suggesting any increase to the estuary from faecal contamination is from other sources. There was some indication of on increasing trend in ammonium two years ago influenced by elevated results around 2005 and 2010, but recent lower levels have shown this trend not to be significant. High ammonium level in 2005 and 2010 may also be from similar sources as faecal contamination. As dairy farming is the predominant land use of the lower plains adjacent to the estuary with over 20,000 dairy cows in the catchment, ammonium and faecal bacteria trends may partly be a result of an increase in dairying intensity in the last decade, along with climatic drivers and estuarine nutrient recycling.

Table 3.8 Trend statistics for Waihi Estuary.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
	Trend	▫	▫	▫	⬈	⬈	⬈
Waihī Estuary	**%/yr (RSEN)**	2.02	-1.08	0	**7.50**	**8.03**	**6.04**
	Slope (10^{-3} units/yr)	243	-24	0	19	36	44

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
	Trend	▫	▫	▫	▫	▫
Waihī Estuary	**%/yr (RSEN)**	<0.01	1.79	-0.7	-0.97	0.01
	Slope (10^{-3} units/yr)	<0.01	0.2	1.7	-0.2	0.1

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ⬈⬊ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in Appendix A.8).

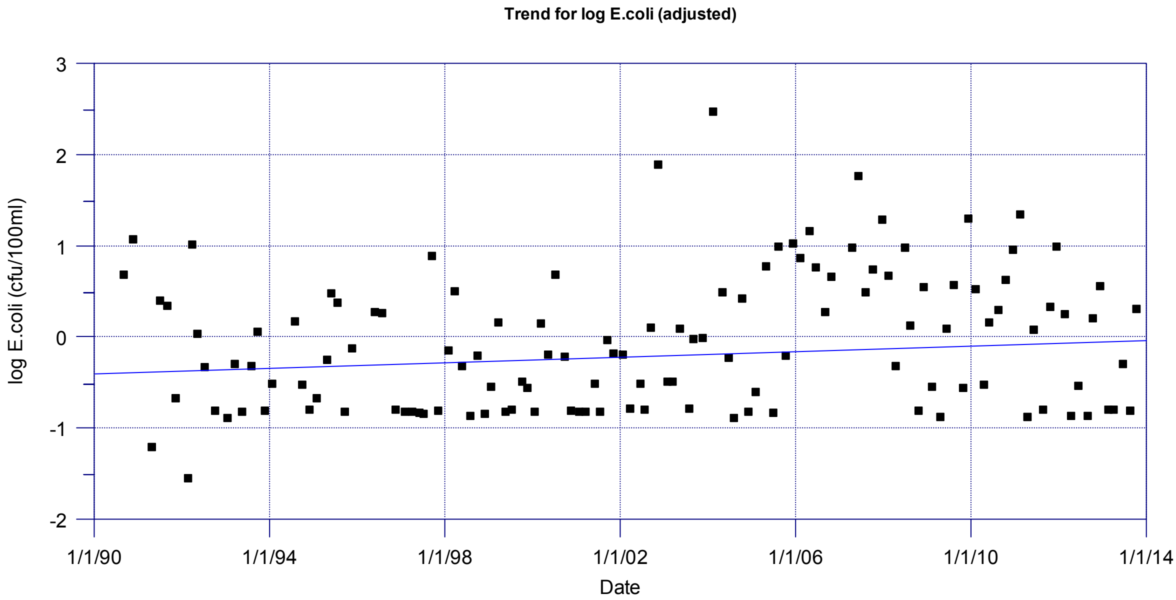


Figure 3.22 Sen slope trend log10 E.coli, Waihī Estuary.

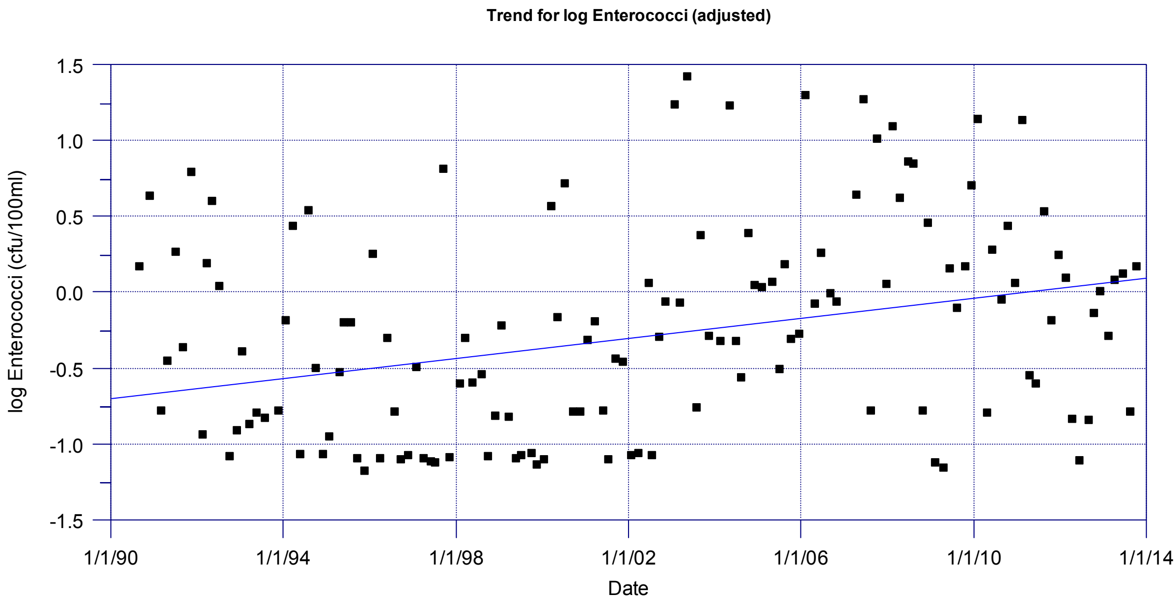


Figure 3.23 Sen slope trend log10 Enterococci, Waihī Estuary.

3.7 Maketu Estuary

The 2.3 km^2 Maketu Estuary is contained in the Kaituna River Catchment where a barrier spit forces the entrance of the estuary towards Okurei Point. The major fresh water input is the 100,000 m^3 per tidal cycle re-diversion of the Kaituna River which occurred at Te Tumu in October 1995 after an absence of 39 years. Several smaller additions from minor streams and drains enter on the southern edges of the estuary.

The lower catchment is similar in nature to the Waihi Catchment. It is dominated by intensive livestock agriculture and horticulture with the additions of the discharges associated with the township of Te Puke and industrial discharges from AFFCO freezing works. The upper Kaituna Catchment encompasses the Rotorua and Rotoiti Lakes catchments as Lake Rotorua discharges through Lake Rotoiti and down the Kaituna River.

Water quality statistics for the estuary are listed in Appendix 1, Table A.9.

3.7.1 Maketu Estuary trends

Table 3.9 shows one meaningful significant trend over the period 1990 to 2013, that of increasing SS. Higher suspended solids concentrations in the estuary may be the result of a number of factors including a number of wetter than average years from 2002 to 2010. A similar trend is not found further up the Kaituna River or in the Kaituna River estuary, hence it is more likely that processes within the estuary and sediment entering via other inflows explain the trend.

Table 3.9 Water quality statistics for Maketu Estuary.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Maketu Estuary	***Trend***	➚	▫	▫	▫	▫	▫
	%/yr (RSEN)	**2.96**	-2.05	0.02	5.19	1.69	0.06
	Slope (10^{-3} units/yr)	417	-66.5	1.6	15.4	12.5	0.6

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Maketū Estuary	***Trend***	▫	▫	▫	▫	▫	▫
	%/yr (RSEN)	-0.97	1.07	-0.75	0.77	-0.7	-0.25
	Slope (10^{-3} units/yr)	-0.1	0.2	-0.2	2	-0.2	-3.5

Trend: ⇗⇘ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in Appendix A.9).

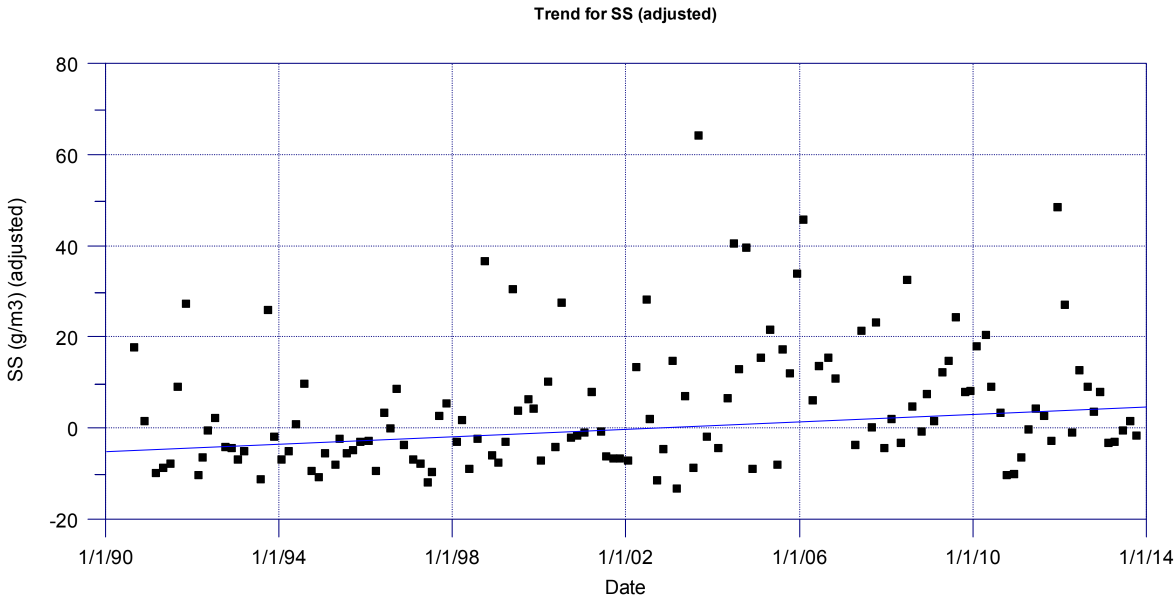


Figure 3.24 Sen slope trend for SS, Maketu Estuary.

3.8 Kaituna River Estuary

The Kaituna River Estuary is approximately 0.2 km² and exits to the ocean at Te Tumu around 3.3 kilometres west of the Maketu Estuary mouth. Originally a flood led to the Kaituna River breaking out at Te Tumu in 1907, but the river migrated back to the Maketu Estuary with help. The river mouth was again diverted through the Te Tumu cut in 1957 with flood control works taking place in 1979.

The catchment area below Lake Rotoiti is approximately 620 km^2 with around the same area again forming the upper catchments of Lakes Rotoiti and Rotorua. Fluctuations and hence water quality in the river tends to be controlled by the lower tributaries due to the buffering effect of the lakes.

The upper regions of the lower Kaituna River catchment (downstream of the lakes) are dominated by pastoral and exotic forestry with some sub-catchments retaining extensive native forest cover. In recent years there has been some conversion of exotic forestry to dairy farms. Much of the mid-section of this catchment has had suitable land converted to horticulture with kiwifruit being dominant. The lower regions of the catchment are predominantly productive river-flat plains with extensive drainage schemes and the dominant land use is dairy farming.

Eutrophication of Lakes Rotoiti and Rotorua continued even with the implementation of the Upper Kaituna Catchment Control Scheme in 1975, and removal of Rotorua's treated sewage in 1991. Installation of the Ohau Channel diversion wall coupled with a suite of other remedial actions in these lake catchments has resulted in greatly improved water quality. In the lower catchment continued horticultural and livestock intensification, industrial discharges and Te Puke treated effluent discharges are likely to be the main drivers of water quality in the Kaituna Estuary.

Sampling occurs downstream of the Maketū Estuary river diversions structure. Water quality statistics are tabulated in Table A.10, Appendix 1.

3.8.1 Kaituna River Estuary trends

Turbidity displays a meaningful significant decreasing trend (Figure 3.25), as does chlorophyll-a (Figure 3.30). Both these parameters show a weak correlation where some of the relationship and decrease in productivity can be explained by a reduction in cyano-bacterial blooms in the Kaituna River.

A meaningful and significant increasing trend in DRP is shown in Figure 3.26. Further up the Kaituna River the trend in DRP is decreasing. These opposing trends may be explained by the recent decrease productivity (chlorophyll-a) measured in the estuary, and hence less up take of DRP by phytoplankton in the estuary.

Ammonium shows a meaningful significant decreasing trend (Figure 3.27) in the Kaituna River estuary. A similar trend is seen further up the Kaituna at Te Matai and is likely to due to the improvements in the discharge from AFFCO, although some high results are still encountered.

Nitrogen in the form of total oxides of nitrogen (TOx-N) are moving in the opposite direction with a meaningful significant increasing trend (Figure 3.28).This is a repeating trend in most of the river estuaries and seems to reflect the increasing agricultural intensity in these catchments.

Enterococci are the only faecal indicator bacteria with a meaningful increasing trend (Table 3.10). This may be due to the characteristics of the point source discharges in the catchment, although enterococci concentrations are similar to other river estuaries in the region.

Table 3.10 Trend statistics for Kaituna Estuary.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Kaituna Estuary	***Trend***	□	↘	□	□	↗	□
	%/yr (RSEN)	-0.74	**-2.27**	0.05	-0.86	**2.0**	-0.5
	Slope (10^{-3} units/yr)	-51.6	**-67.5**	3.6	-16.1	**33**	-10.9

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Kaituna Estuary	***Trend***	↗	↘	↗	□	□	↘
	%/yr (RSEN)	**1.91**	**-3.50**	**1.92**	-1.51	0.25	**-2.67**
	Slope (10^{-3} units/yr)	**0.4**	**-2.3**	**8.7**	11.4	0.1	**54**

Trend: ⇗⇘ significant increasing or decreasing trend of parameter over time ($p<0.05$); ↗↘ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis period given in Appendix A.10, *2005-2013).

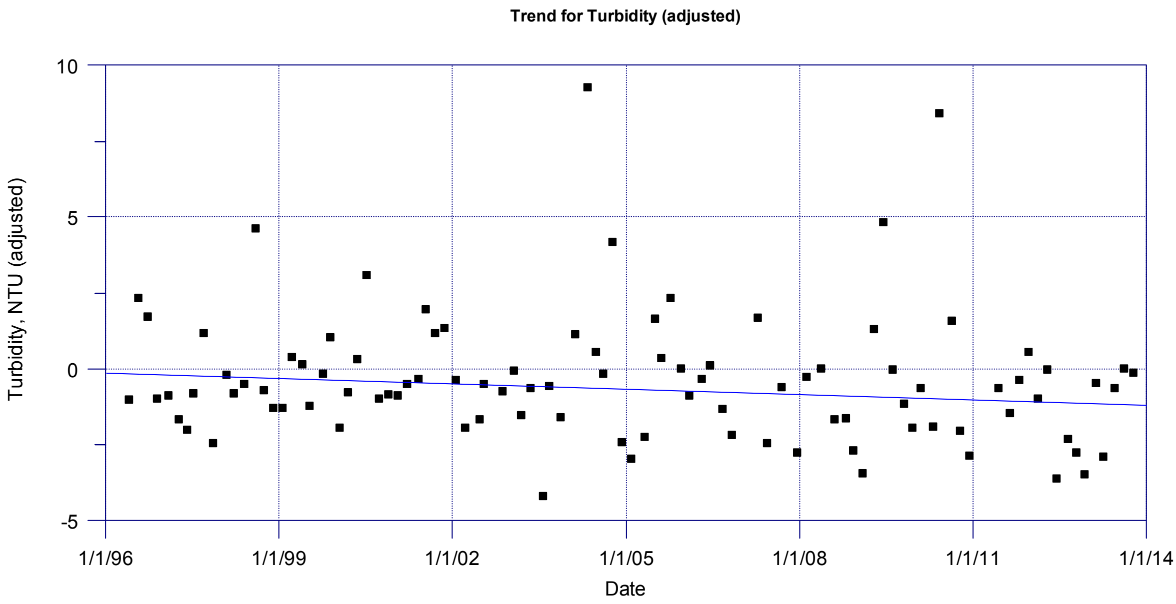


Figure 3.25 Sen slope trend for Turbidity, Kaituna River Estuary.

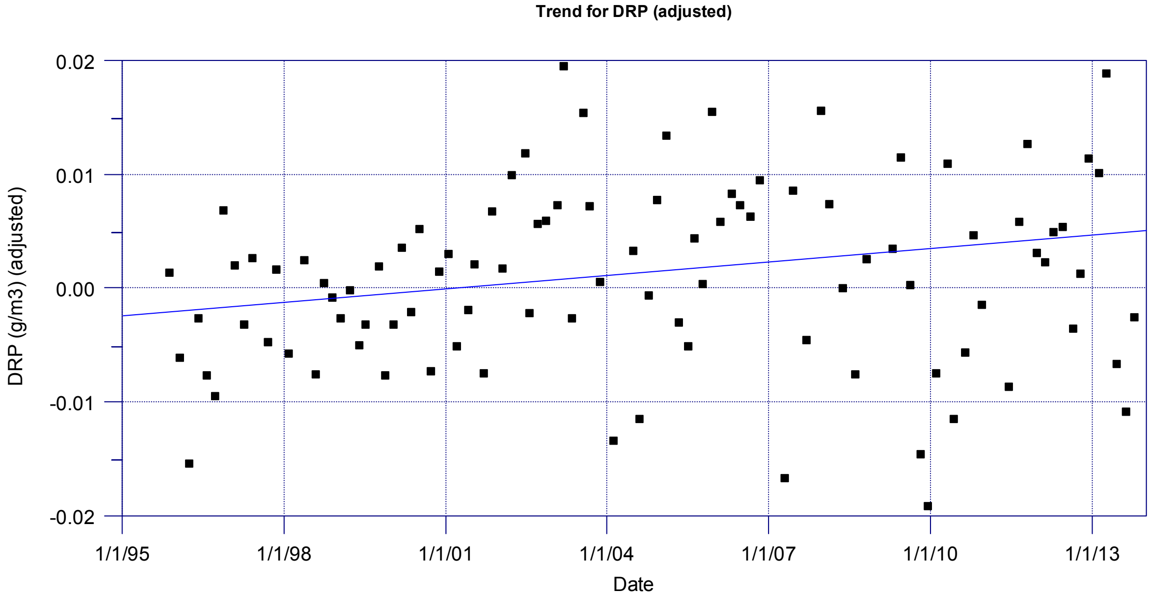


Figure 3.26 Sen slope trend for DRP, Kaituna River Estuary.

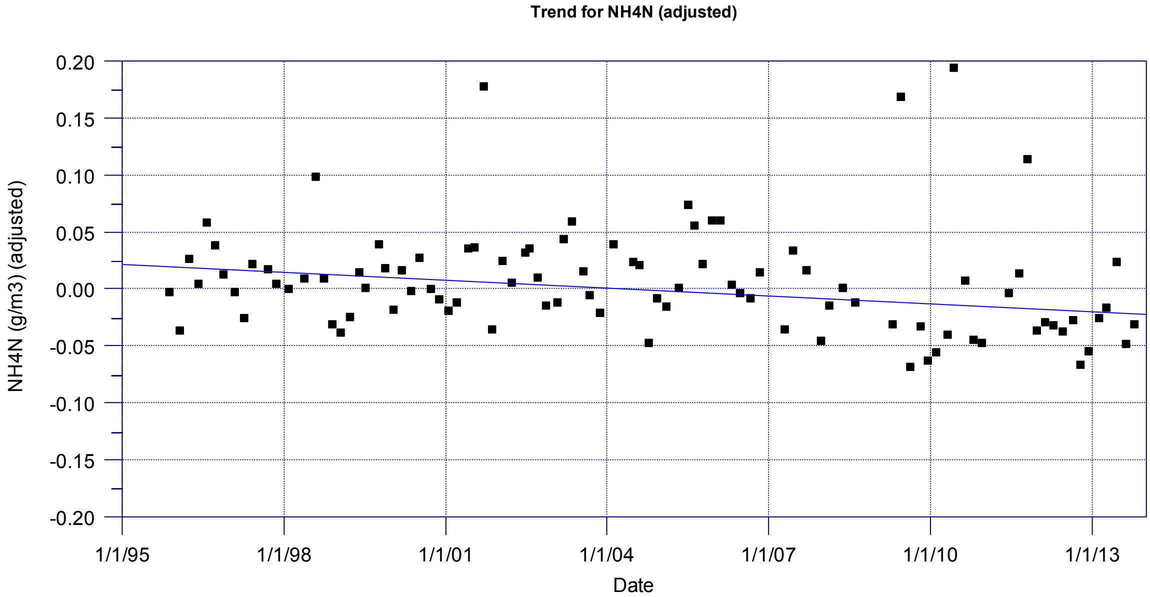


Figure 3.27 Sen slope trend for NH_4-N, Kaituna River Estuary.

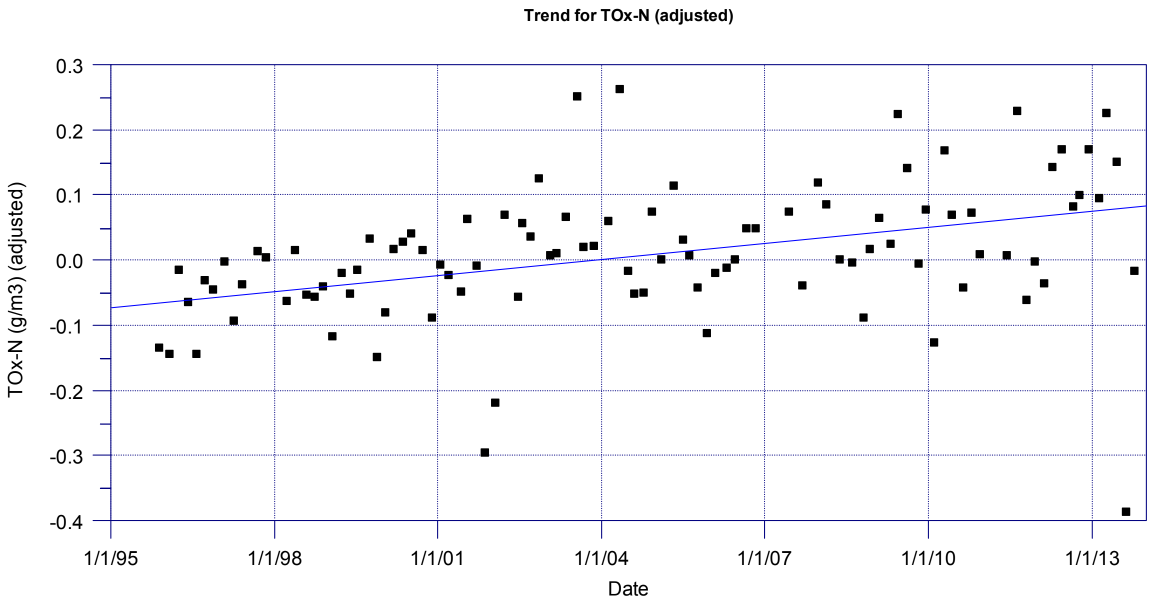


Figure 3.28 Sen slope trend for TOx-N, Kaituna River Estuary.

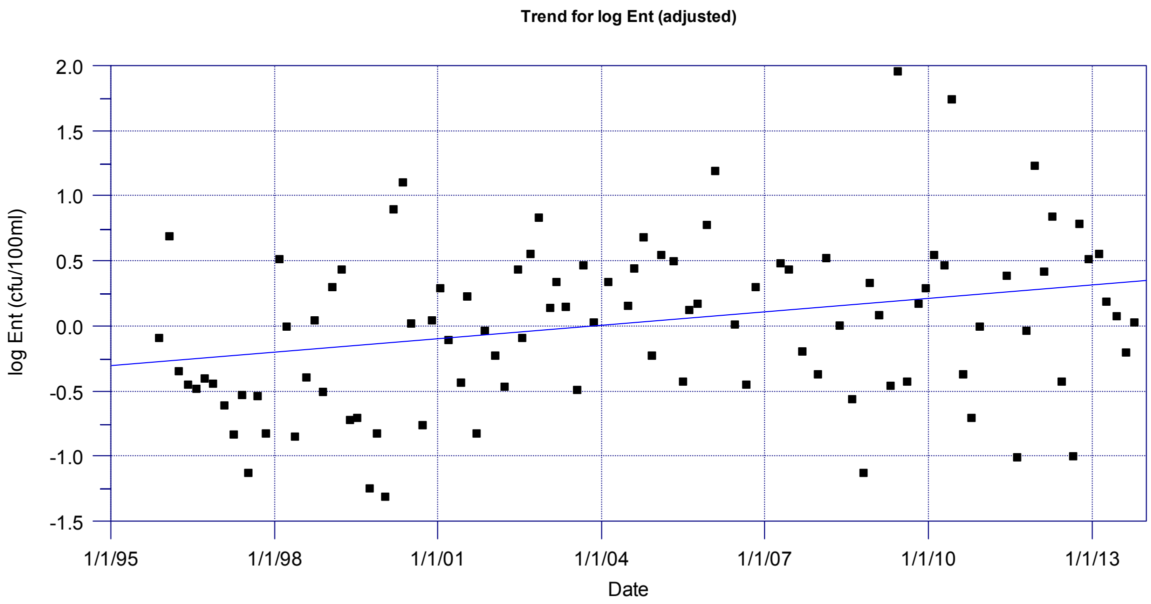


Figure 3.29 Sen slope trend for log enterococci, Kaituna River Estuary.

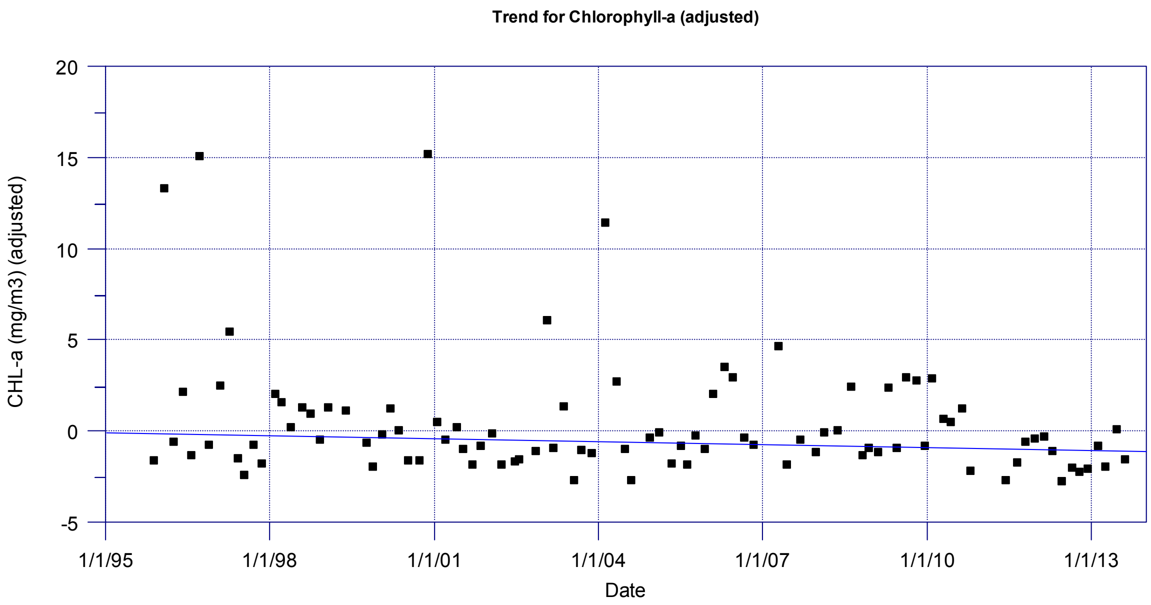


Figure 3.30 Sen slope trend for chlorophyll-a, Kaituna River Estuary.

3.9 Tauranga Harbour

Tauranga Harbour is a large tidal estuarine inlet with two entrances and a total area of 201 km^2. The estuarine lagoon is impounded by a barrier island (Matakana Island) and two barrier tombolos. Mount Maunganui at the southern entrance and Bowentown to the north (Park, 1991). The estuary is predominantly shallow with approximately 66% of its total area being intertidal.

There are three main harbour basins. The largest basin is in the north and this is separated from the southern basins by intertidal flats in the centre of the harbour. The other basin is smaller and includes several sub-estuaries and large bays. At mean high water the northern basin has a volume of approximately 177,702,000 m^3 and the southern basin a volume of 277,518,000 m^3.

The northern harbour catchment is the smallest with a total area of 270 km^2 and a mean freshwater inflow of 4.1 m^3/s. The Wairoa River catchment at 460 km^2 and mean freshwater inflow of 17.6 m^3/s is the largest feeding into Tauranga Harbour. In the northern harbour the freshwater inflow represents only 0.1% of the harbour volume per tidal cycle while the southern input represents 0.48%.

The harbour catchment covers an area of approximately 1,300 km^2 and is used extensively for horticulture and agriculture. At the southern end of the harbour, the city of Tauranga and surrounding area supports a large residential population (around 115,000). Near the southern entrance the harbour has well developed port facilities. For more detail on sub-catchment areas and land use, see Park, 2003 or Hume et al., 2009.

3.9.1 Southern Harbour

The southern catchment has a total area of 1,030 km^2 and a mean freshwater inflow of 30.5 m^3/s. It encompasses most of the Tauranga city urban area and so has the greatest population numbers in its catchment.

For the purposes of presenting water quality data the southern basin has been split into two parts. One area is represented by sampling points located in Rangataua and Waipu Bays, known as Town Basin the other area is the Otumoetai Channel in the main southern part of the harbour just to the east of the Wairoa Estuary. Water quality trends for the southern harbour are summarised in Table A.11 to A15, Appendix 1.

3.9.2 Town Basin trends

Monitoring is presented from four sites: Maungatapu Bridge; Grace Street (low tide); Waipu Bay and Whareroa Point Marina. Grace Street is monitored during low tide conditions and analysis has only occurred for nutrients, SS and turbidity while the other two sites are monitored during mid to high tide conditions. Water quality statistics are tabulated in Table A.11-14, Appendix 1.

Turbidity has been analysed over a 15 year period displaying a meaningful decreasing trend (Table 3.11, Figure 3.31) at Maungatapu. Changes in both suspended solids (SS) and phytoplankton (as measured by chlorophyll-a impact on turbidity. Neither SS nor chlorophyll-a exhibit a significant long-term trend, but there has been some improvement in SS over the period 2008 to 2013 which may have also contributed to the improvement in turbidity. Over the shorter analysis period 1998 to 2013, SS at Whareroa Point has shown a significant increasing trend (Figure 3.35), primarily due to an increase in SS concentrations in 2004-2005 and a recent increase. No correlation with other parameters is apparent at this site, although a meaningful trend of increasing chlorophyll-a at Whareroa Point (Figure 3.35) does have maximums during a similar period as SS maximum concentrations. This would suggest that increases in SS are often due to increased algal biomass in the water column.

Both dissolved inorganic forms of nitrogen (NH_4-N and TOx-N) have shown increasing trends over the past two decades (Figures 3.30 and 3.31) at Maungatapu. The other two high tide Town Basin sites show no trend in dissolved nitrogen and generally have lower concentrations reflecting the greater influence of oceanic waters.

Like turbidity, TP also shows a meaningful decreasing trend at Maungatapu (Figure 3.32) a trend that is repeated both at Waipu Bay and Grace Street (Figures 3.35 and 3.36). TP is highly correlated with both SS and turbidity at Grace Road (Pearson R=0.682 and 0.802, respectively, $p<0.01$), and TP has a weaker correlation with turbidity at Maungatapu and Waipu (Pearson R=0.577 and 0.49 respectively, $p<0.01$). Decreasing TP and turbidity may show an improvement in the amount of fine sediment being transported into Town Basin.

Some improvement in *E.coli* concentrations was seen at Grace Street under low tide conditions with a meaningful decreasing trend (Figure 3.38). Other sites displayed no significant long term trends of indicator bacteria species.

Table 3.11 Trend statistics for Maungatapu at bridge.

Site		**SS** (g/m^3)	**Turbidity** (NTU)	**pH**	**E.coli** (cfu /100 ml)	**Ent** (cfu /100 ml)	**FC** (cfu /100 ml)
	Trend	▫	↘	▫	▫	▫	▫
Maungatapu	**%/yr (RSEN)**	0.0	**-3.73**	0.0	2.82	0.81	0.26
	Slope (10^{-3} units/yr)	0.3	**-117**	0.3	13	6	2

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Maungatapu	***Trend***	▫	⬀	**➚**	▫	**➘**	▫
	%/yr (RSEN)	0.00	**0.84**	**1.55**	2.1	**-1.68**	-2.34
	Slope (10^{-3} units/yr)	0	**0.4**	**0.9**	6	**-0.4**	-20

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); **➚➘** significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis periods given in Table A.11).

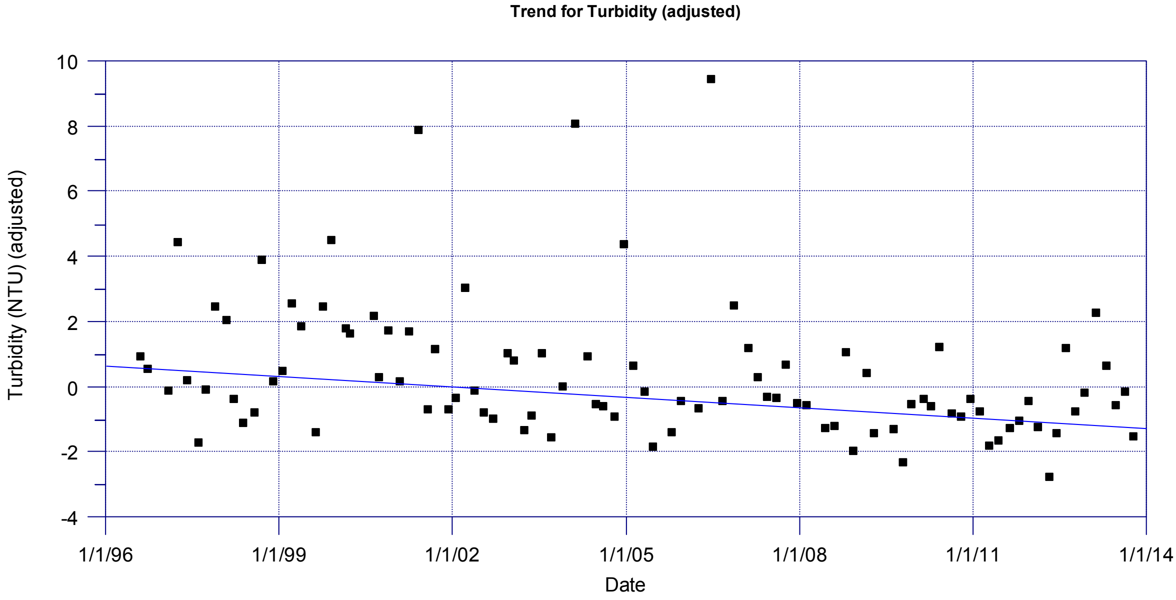


Figure 3.31 Sen slope trend for Turbidity, Maungatapu, Tauranga Harbour.

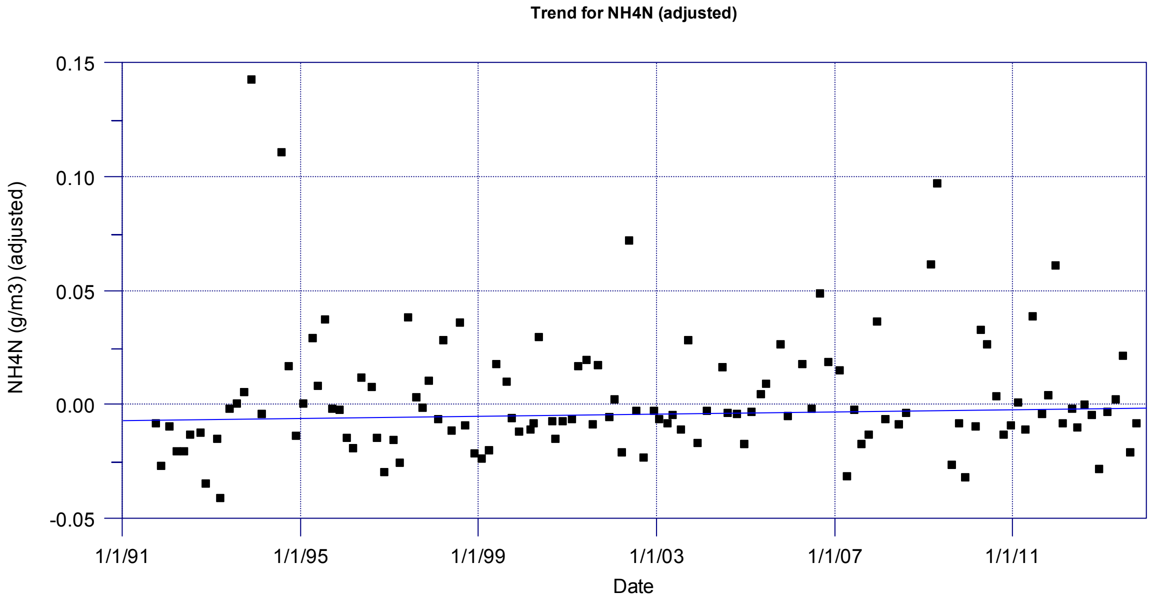


Figure 3.32 Sen slope trend for NH_4-N, Maungatapu, Tauranga Harbour.

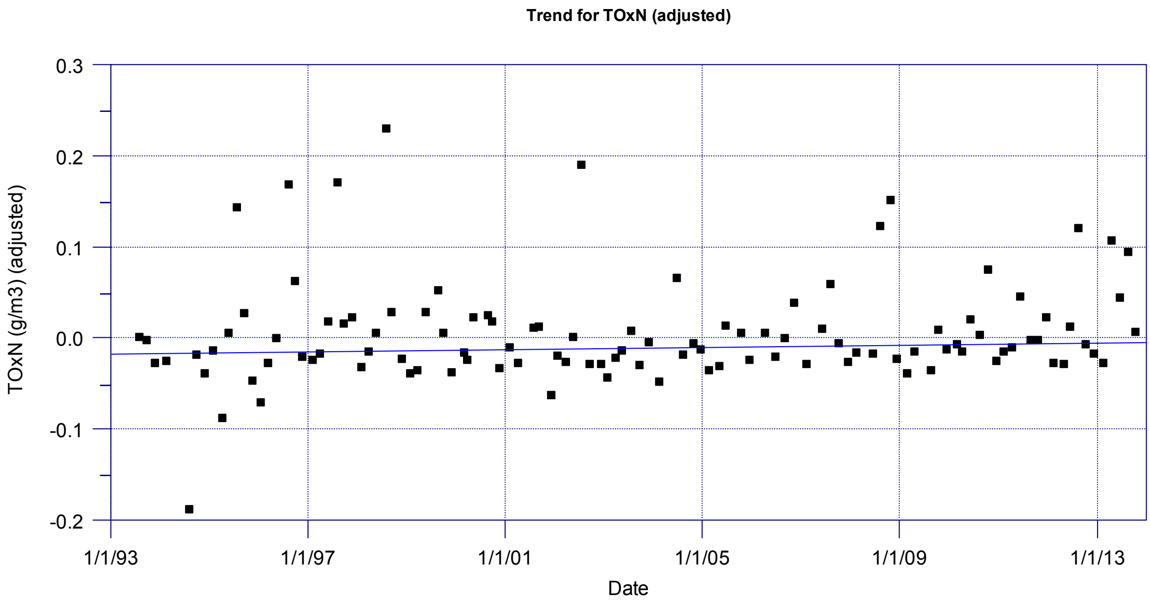


Figure 3.33 Sen slope trend for TOx-N, Maungatapu, Tauranga Harbour.

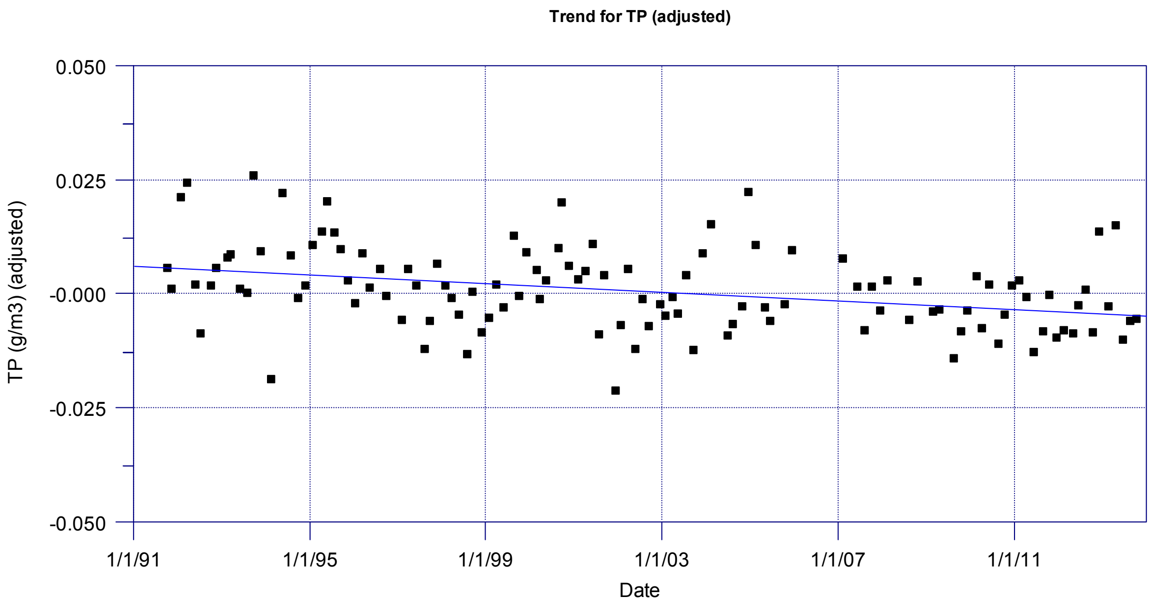


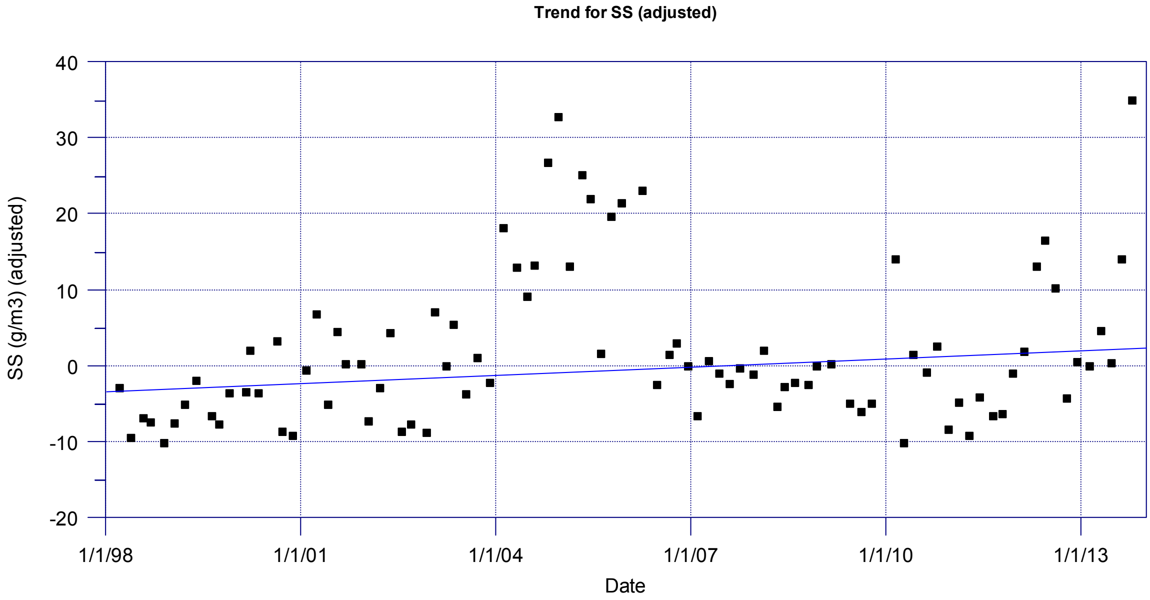
Figure 3.34 Sen slope trend for TP, Maungatapu, Tauranga Harbour.

Table 3.12 Trend statistics for Whareroa Point Marina.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Whareroa Point Marina	***Trend***	↗	□	□	□	□	□
	%/yr (RSEN)	**3.16**	-1.55	-0.02	4.2	4.33	1.61
	Slope (10^{-3} units/yr)	**357**	28	2	11	8	16

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Whareroa Point Marina	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	▫	▫	▫	➚
	% change/year	-1.43	1.18	2.19	0.51	0.0	**2.88**
	Slope (units/yr)	0.1	0.4	1	1	<0.1	**22**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time (p<0.05); ➚➘ significant and meaningful trend (p<0.05, %/yr >1%); ▫ not significant. (Analysis period given in



Appendix A.12).

Figure 3.35 Sen slope trend for SS, Whareroa Point, Tauranga Harbour.

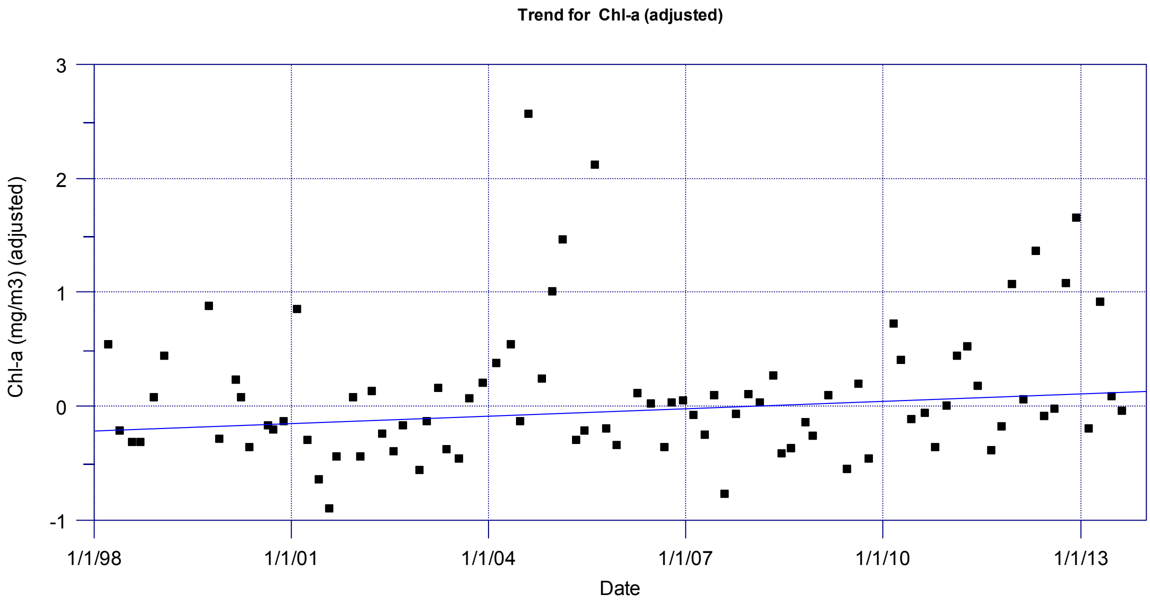


Figure 3.36 Sen slope trend for Chl-a, Whareroa Point, Tauranga Harbour.

Table 3.13 Trend statistics for Waipu Bay.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Waipu Bay	***Trend***	□	□	□	□	□	□
	%/yr (RSEN)	-11.2	-2.31	0.01	-11.4	0.59	-2.09
	Slope (10^{-3} units/yr)	-1924	-52	0.4	-48	18	-22

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Waipu Bay	***p*-value (trend slope 10^{-3} units/yr)**	□	□	□	□	➘	□
	% change/year	-7.35	-2.94	2.38	0.73	**-5.92**	3.7
	Slope (units/yr)	-0.5	1	1	2	**-1**	27

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis period given in table A.13, Appendix 1)).

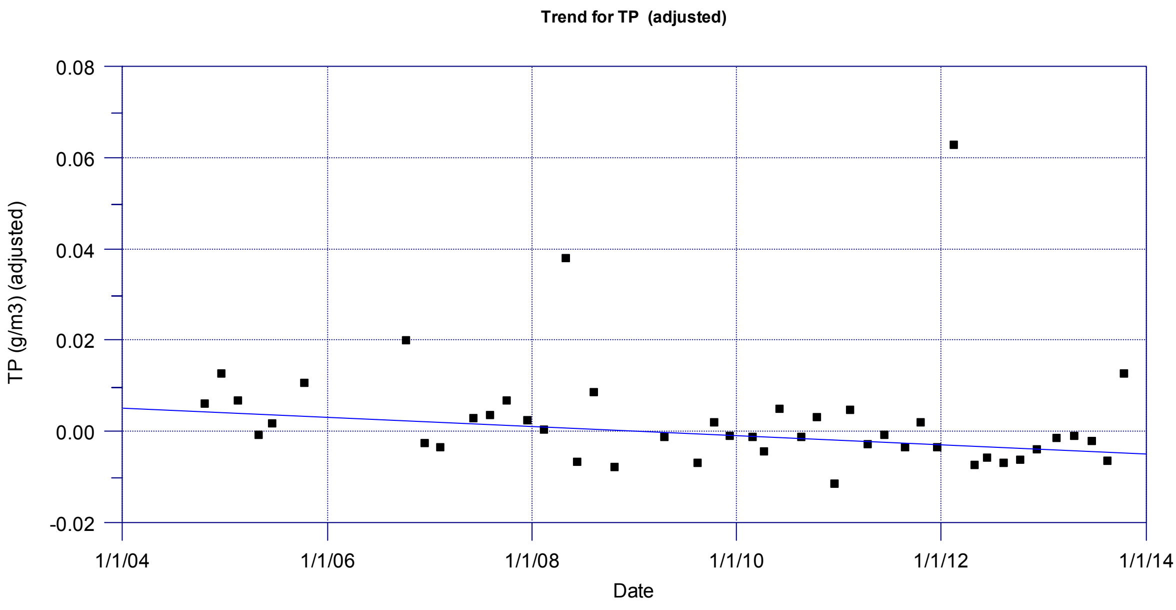


Figure 3.37 Sen slope trend for TP, Waipu Bay, Tauranga Harbour.

Table 3.14 Trend statistics for Grace Street.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli* (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Grace Street	***Trend***	□	□	□	↘	□	□
	%/yr (RSEN)	1.13	-0.74	0.03	-13.6	0.1	-15.6
	Slope (10^{-3} units/yr)	255	-38	2.4	-58.4	0.3	-70

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)
Grace Street	***p*-value (trend slope 10^{-3} units/yr)**	↘	□	□	□	↘
	% change/year	**-2.60**	<0.01	-1.13	0.56	**-2.10**
	Slope (units/yr)	**-2**	<0.01	-0.8	2.3	**-0.7**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time (p<0.05); ↗↘ significant and meaningful trend (p<0.05, %/yr >1%); □ not significant. (Analysis period given in

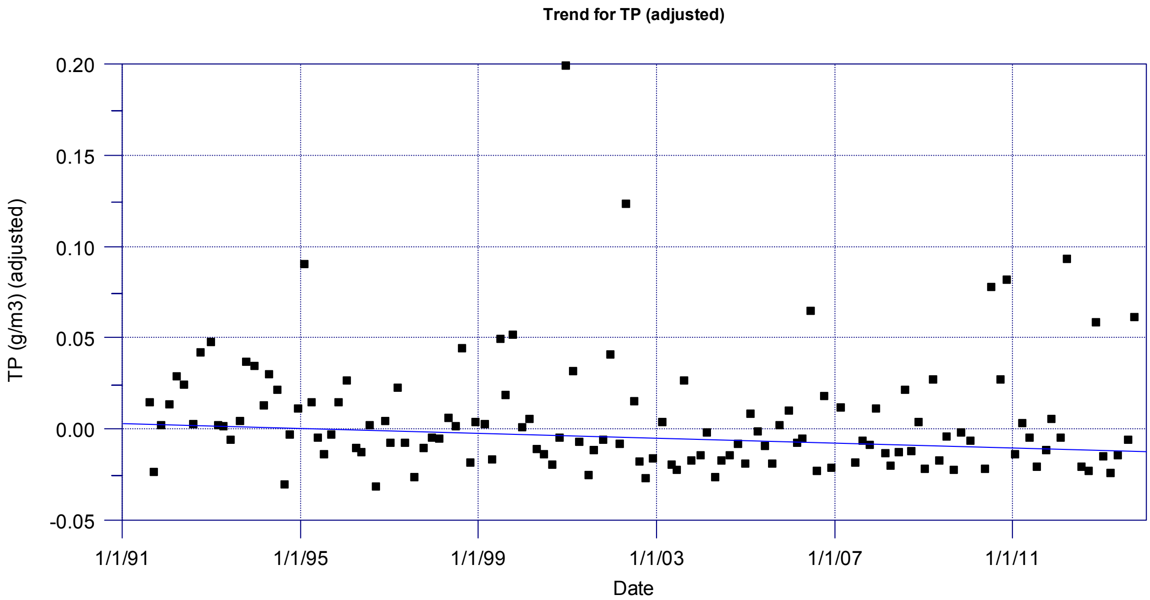


table 3.14, Appendix 1). *2005 to 2013.

Figure 3.38 Sen slope trend for TP, Grace Street, Tauranga Harbour.

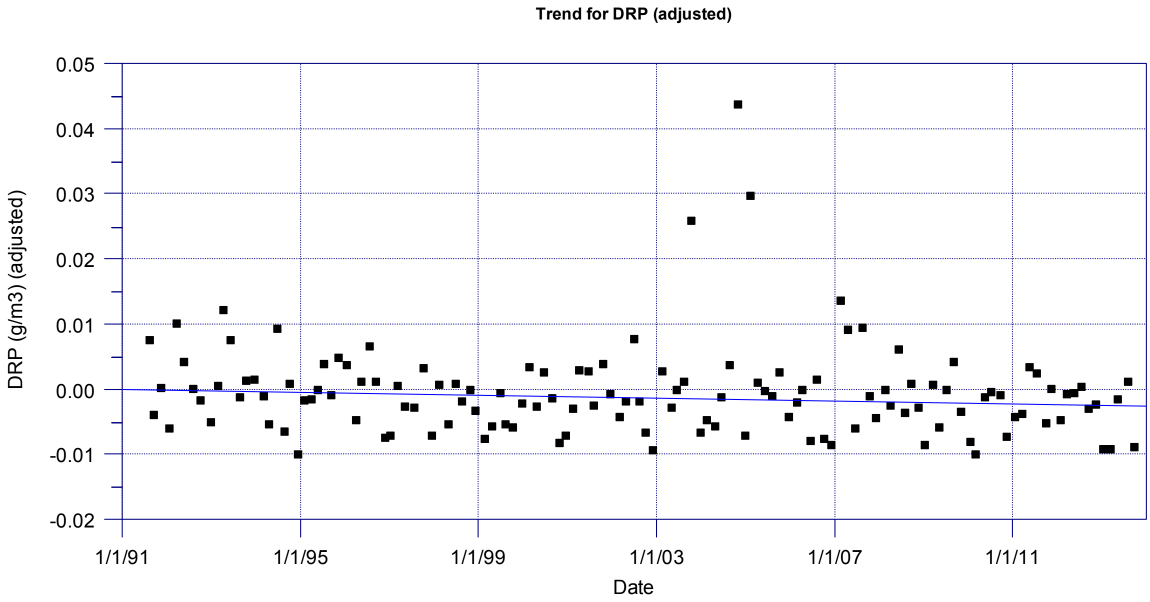


Figure 3.39 Sen slope trend for DRP, Grace Street, Tauranga Harbour.

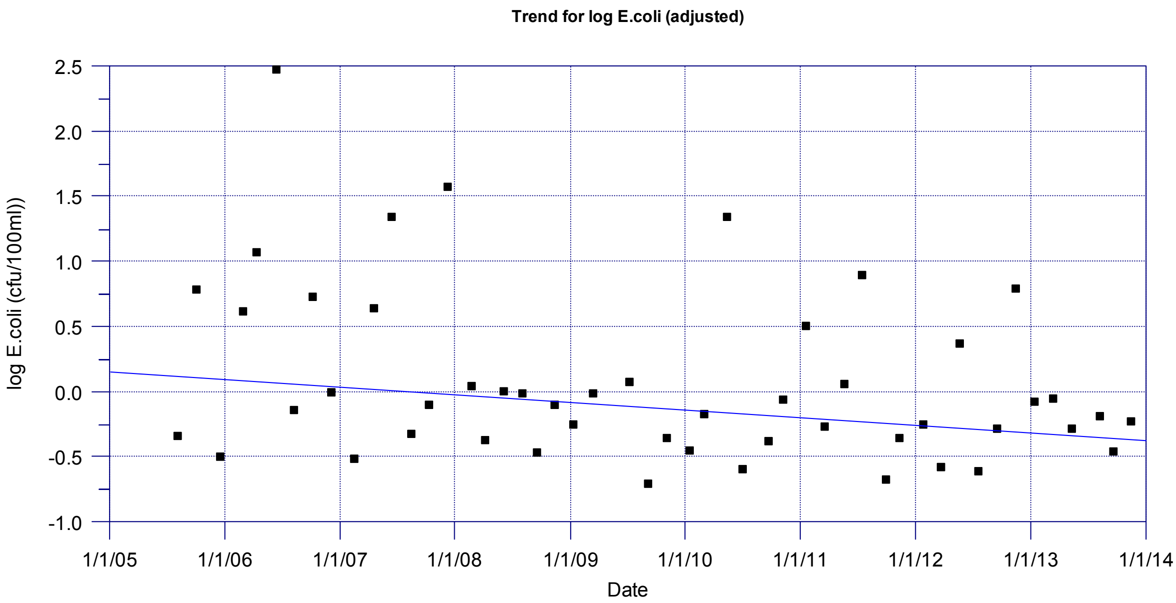


Figure 3.40 Sen slope trend for log10 E.coli, Grace Street, Tauranga Harbour.

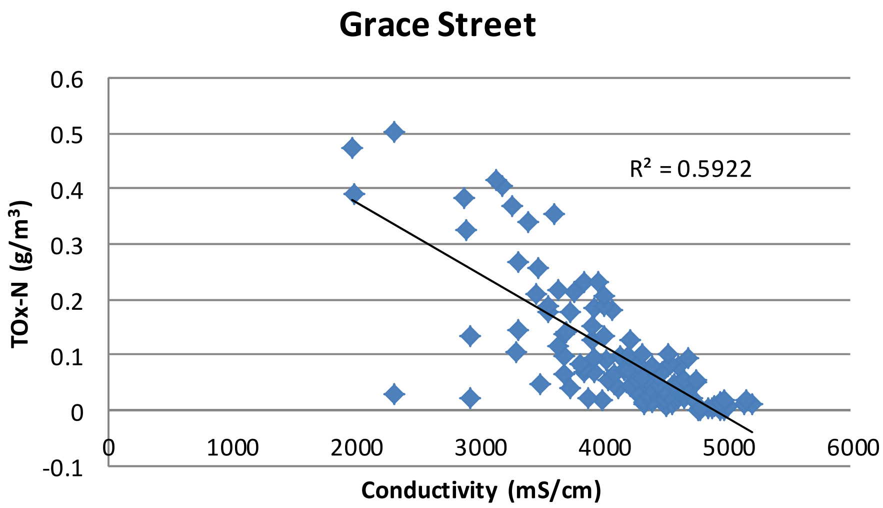


Figure 3.41 Conductivity vs TOx-N, Grace Street, Tauranga Harbour.

The low tide site Grace Street exhibits higher TOx-N concentrations at lower conductivities (or salinity) as show in Figure 3.41. The influence of freshwater on the saline environment can be seen in this low tide environment and to a lesser extent in the upper estuary at Maungatapu (R^2 = 0.433).

3.9.3 Outmoetai Channel trends

Monitoring of the Otumoetai Channel is performed at two sites named Otumoetai Beach Road (high tide) and Otumoetai Kulim Avenue (low tide). The Pilot Bay site was added in 2007 and is influenced by water from the Otumoetai Channel as it joins to the entry of water to and from Town Basin. Pilot Bay is representative of water adjacent to the Mount Maunganui port complex. Water quality statistics for the sites are given in Appendix 1, Tables A1.15-17.

Common trends amongst these sites were: Otumoetai low and high tide sites have meaningful decreasing TP and DRP for Otumoetai and Pilot Bay. Figure 3.42 shows the meaningful significant trend of increasing SS at Otumoetai (Table 3.15), but no significant trend was found at the other two sites. Due to the shallow depth of the inter-tidal area this site is impacted by wave and wind action as well as the freshwater input from the Wairoa River. Previous analysis of wind speed and SS showed a positive significant correlation (see Scholes, 2005), however the significance of this correlation between wind speed and SS at this site has reduced with an extra six years of data. While wind plays a significant role in re-suspending inorganic and organic sediment into the water column, phytoplankton growth and turbid freshwater inputs also impact turbidity and suspended solids concentrations. For Otumoetai (high tide site), correlation of turbidity and chlorophyll-a against TP (respectively Pearson R=0.515, R=0.515; $p<0.01$) is likely indication that TP is often associated with phytoplankton. Phytoplankton, predominantly from oceanic water, will also influence turbidity depending on the distribution and abundance of organisms. TP, a parameter often associated with sediment in freshwater systems, has a much stronger association with SS at low tide conditions due to the much higher concentration of both these parameters.

The indicator bacteria enterococci and faecal coliforms both show meaningful significant increasing trends at the Otumoetai high tide site (Table 3.15, Figures 3.44 and 3.45) but E.coli show a decreasing trend at the Kulim low tide site. Weak correlation of these indicator bacteria with SS could indicate bacteria numbers will increase when conditions occur that re-suspend or introduce suspended material into the water column. Bacteria often bind to sediment particles; hence this is a regular association.

Table 3.15 Trend statistics for Otumoetai Bay (high tide site).

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Otumoetai	***Trend***	⬈	□	□	□	⬈	⬈
	%/yr (RSEN)	**8.36**	0.32	0.02	10.49	**6.8**	**3.56**
	Slope (10^{-3} units/yr)	**651**	5	1	16	**32**	**31**

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Otumoetai	***p*-value (trend slope 10^{-3} units/yr)**	⬊	□	□	□	□	□
	% change/year	**-1.69**	-0.98	-2.52	2.37	-1.11	2.14
	Slope (units/yr)	**-0.1**	-0.2	-0.4	7	-0.2	13

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ⬈⬊ significant and meaningful trend ($p<0.05$, %/yr >1%); □ not significant. (Analysis period given in table 3.15, Appendix 1, *2005-2013).

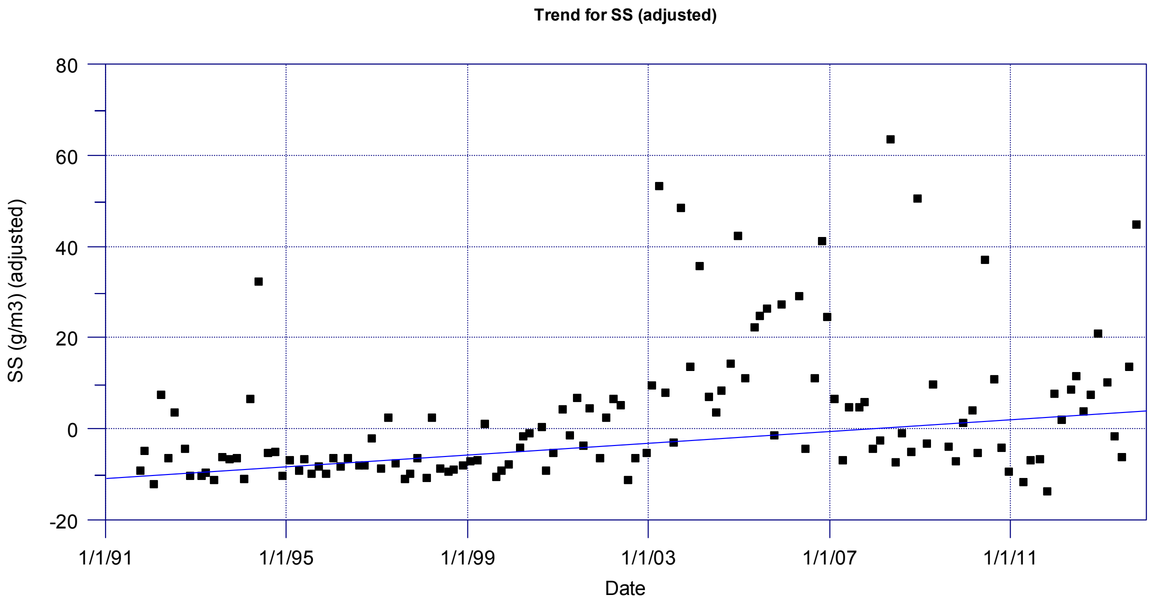


Figure 3.42 Sen slope trend for SS, Otumoetai (high tide), Tauranga Harbour.

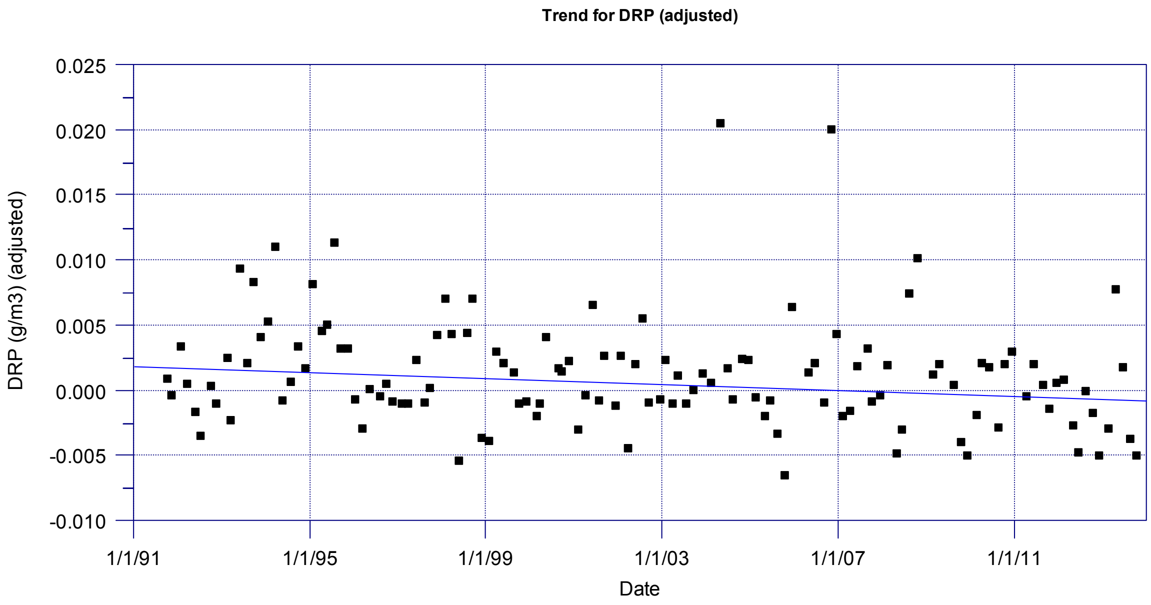


Figure 3.43 Sen slope trend for DRP, Otumoetai (high tide), Tauranga Harbour.

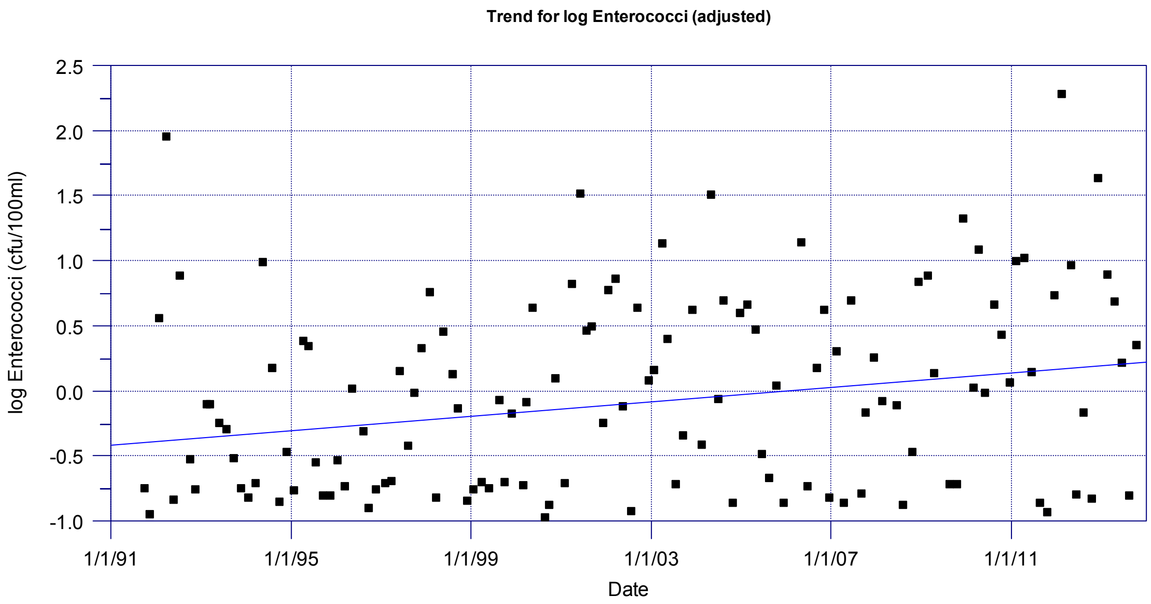


Figure 3.44 Sen slope trend for log Enterococci, Otumoetai (high tide), Tauranga Harbour.

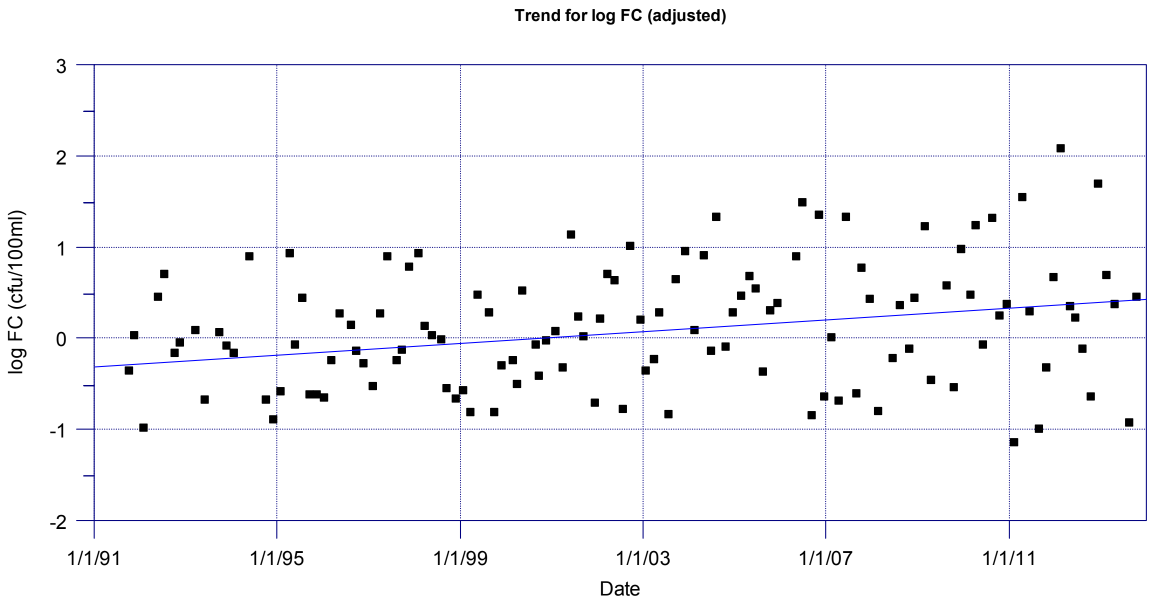


Figure 3.45 Sen slope trend for log faecal coliform, Otumoetai (high tide), Tauranga Harbour.

Table 3.16 Trend statistics for Otumoetai Kulim Ave. (low tide site).

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli* (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Otumoetai Kulim	***Trend***	▫	▫	▫	↘	▫	▫
	%/yr (RSEN)	1.88	-0.71	-0.01	-18	-3.2	12.5
	Slope (10^{-3} units/yr)	246	12	-0.7	71	2	34

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Otumoetai Kulim	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	▫	▫	↘	na
	% change/year	-1.54	-1.38	-7.05	0.72	**-2.8**	na
	Slope (units/yr)	-0.1	-0.2	-0.7	2.1	**-0.6**	na

Trend: ⇗⇘ significant increasing or decreasing trend of parameter over time ($p<0.05$); ↗↘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in table 3.16, Appendix 1). na = insufficient data; *2005 to 2013.

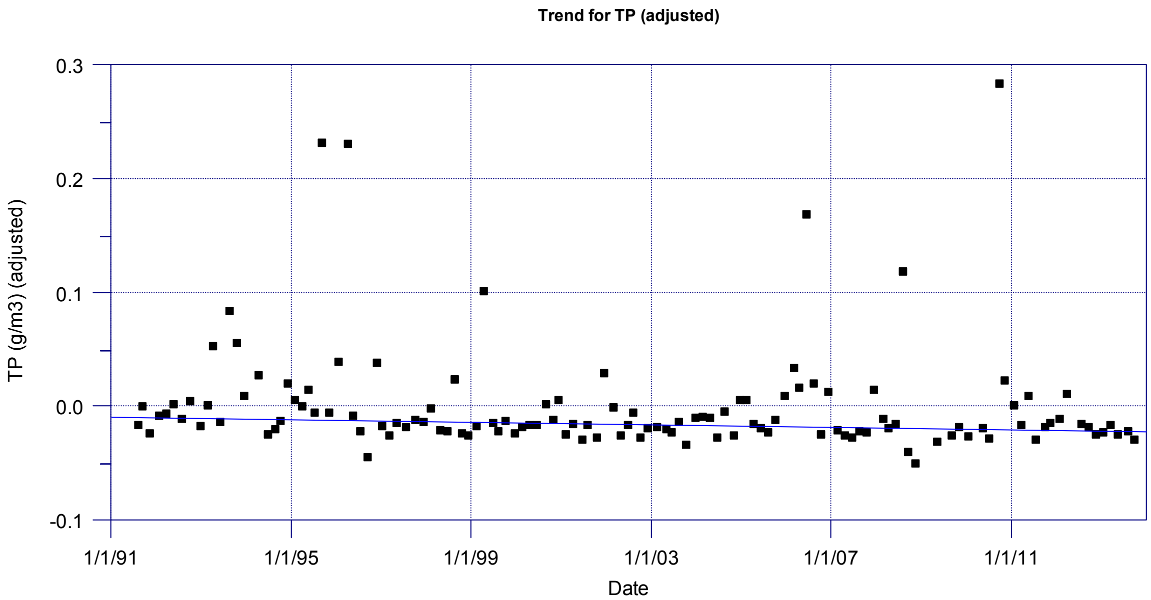


Figure 3.46 Sen slope trend for TP, Otumoetai Kulim Ave, Tauranga Harbour.

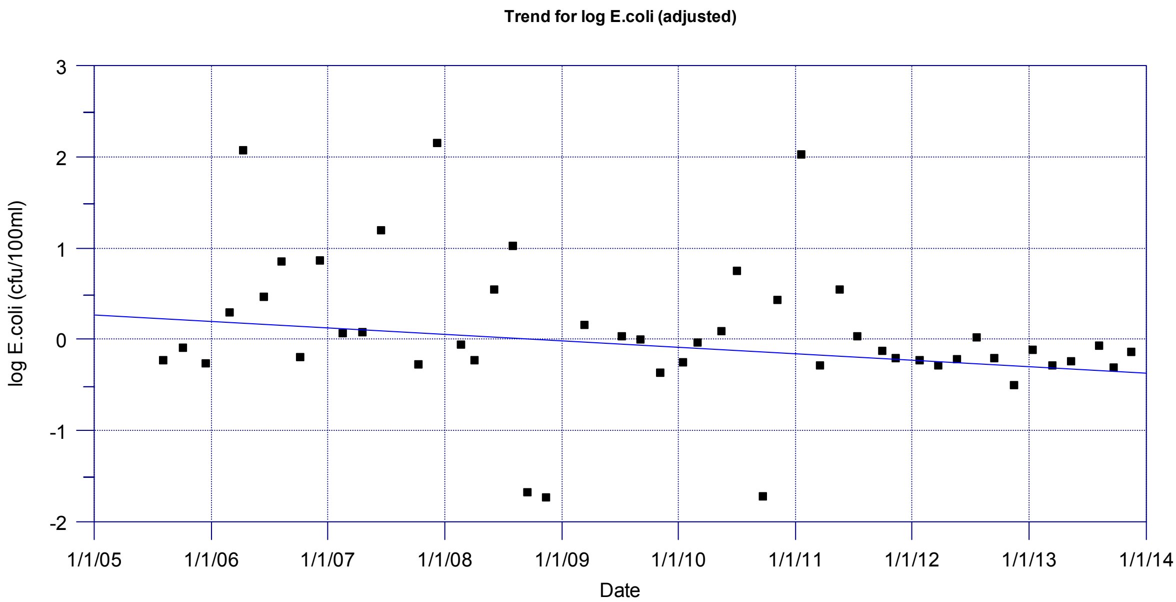


Figure 3.47 Sen slope trend for log10 E.coli, Otumoetai Kulim Ave, Tauranga Harbour.

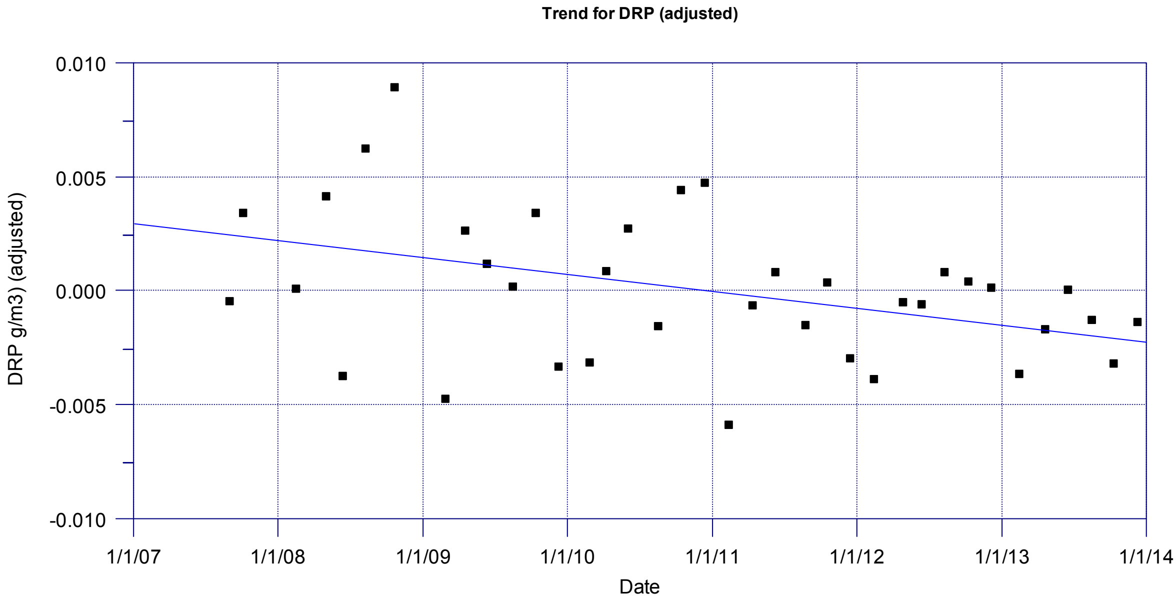
Increasing TN (meaningful and significant, 2005 to 2013) was also found at Pilot Bay. As this trend period is shorter than at other sites it may be influenced more strongly by annual variations as seen at other sites. TN does not appear to be correlated to dissolved nitrogen parameters or chlorophyll-a, and is negatively correlated with SS (Pearson R=-0.522, p<0.01). A large amount of unprocessed pine is loaded onto the adjacent wharf and it is possible that dissolved organic nitrogen is coming from this source influencing the waters here with increased organic nitrogen.

Table 3.17 Trend statistics for Pilot Bay.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
	Trend	□	□	□	□	□	□
Pilot Bay	**%/yr (RSEN)**	1.33	-7.44	0.06	-2.5	-266	-5.4
	Slope (10^{-3} units/yr)	191	-111	5	-3.6	-62	-17.3

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
	***p*-value (trend slope 10^{-3} units/yr)**	➘	□	□	➚	□	□
Pilot Bay	**% change/year**	**-11.59**	1.37	-3.59	**6.12**	-2.01	5.18
	Slope (units/yr)	**-0.8**	0.2	-0.9	**11**	-0.3	47

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time (p<0.05); ➚➘



significant and meaningful trend (p<0.05, %/yr >1%); □ not significant. (Analysis period 2007-2013).

Figure 3.48 Sen slope trend for DRP, Pilot Bay, Tauranga Harbour.

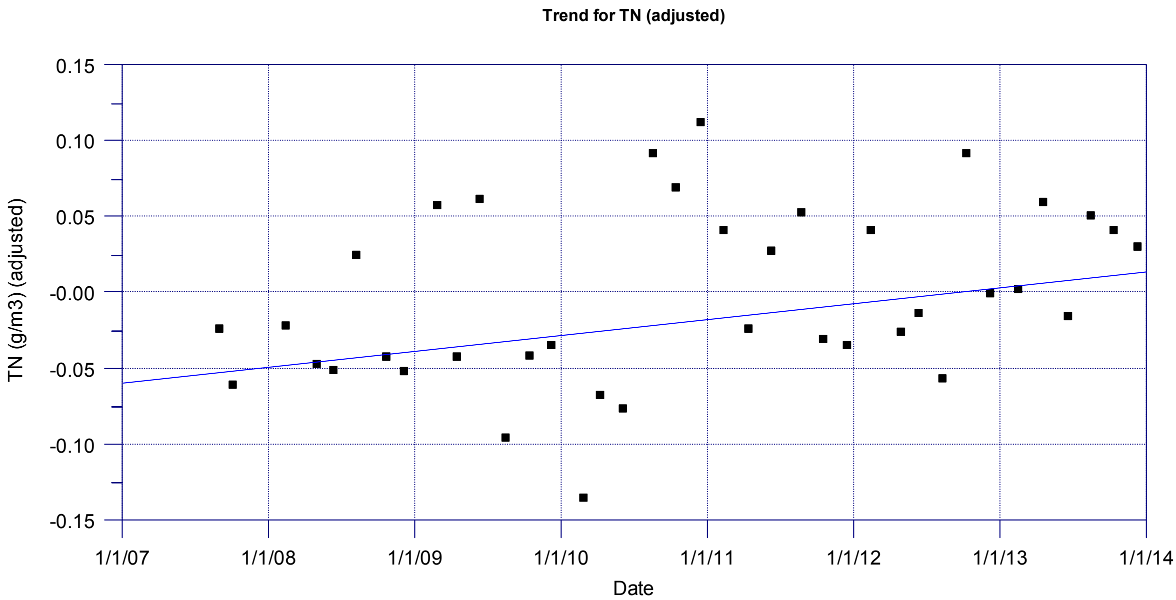


Figure 3.49 Sen slope trend for TN, Pilot Bay, Tauranga Harbour.

3.9.4 South Basin trends

The South Basin water quality has been monitored predominantly at two sites, Te Puna and Omokoroa with a third site added at Pahoia in 1998. All sites are monitored mid-tide to high tide. Tables 3.18 to 3.20 display the trends analysis for the three sites over the sites monitoring periods. Water quality statistics for each of the sites is given in Appendix 1.

Similar to Otumoetai, Te Puna also displays meaningful significant increasing trends for SS, enterococci, and faecal coliforms (Table 3.18, Figures 3.50-3.52). Omokoroa also has increasing trends for the indicator bacteria *E.coli*, and enterococci (Table 3.19). However, at both sites indicator bacteria are generally at low levels, and are weakly negatively correlated with salinity. Faecal contamination may often be associated with freshwater inputs, particularly given the proximity of the Wairoa River, Tauranga Harbour's largest freshwater input.

TOx-N at Omokoroa shows an increasing meaningful trend (Table 3.19). Both dissolved inorganic nitrogen parameters (TOx-N) and NH_4-N) display strong seasonal patterns with winter maximums and summer minimums, as does DRP. Such seasonality reflects not only the freshwater inputs of dissolved inorganic nitrate-nitrogen to the estuary but also the uptake by marine plants (macroalgae and phytoplankton) with growth in warmer waters. Omokoroa has a trend of decreasing phytoplankton (Figure 3.58).

No significant trend for TN was found in recent data (2006 to 2013), but examination of annualised data for Omokoroa and Te Puna indicate an increase in TN has occurred from 1994 to 2013 (Table 3.19, Figure 3.53). TN was not analysed from 1996 to 2005.

Table 3.18 Trend statistics for Te Puna.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Te Puna	***Trend***	↗	▫	▫	▫	↗	↗
	%/yr (RSEN)	**5.09**	-1.30	0.01	2.38	**9.62**	**4.75**
	Slope (10^{-3} units/yr)	**555**	-21	1	4	**15**	**28**

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN* (g/m³)	TP (g/m³)	Chl-a # (mg/m³)
Te Puna	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	▫	▫	▫	▫
	% change/year	-2.08	1.20	2.16	0.73	-0.56	2.66
	Slope (units/yr)	-0.1	0.3	0.3	2	-0.1	22

Trend: ⇗⇘ significant increasing or decreasing trend of parameter over time (p<0.05); ↗↘ significant and meaningful trend (p<0.05, %/yr >1%); ▫ not significant. (Analysis period given in Appendix 1, Table A.18; *2006-2013, #1998-2013).

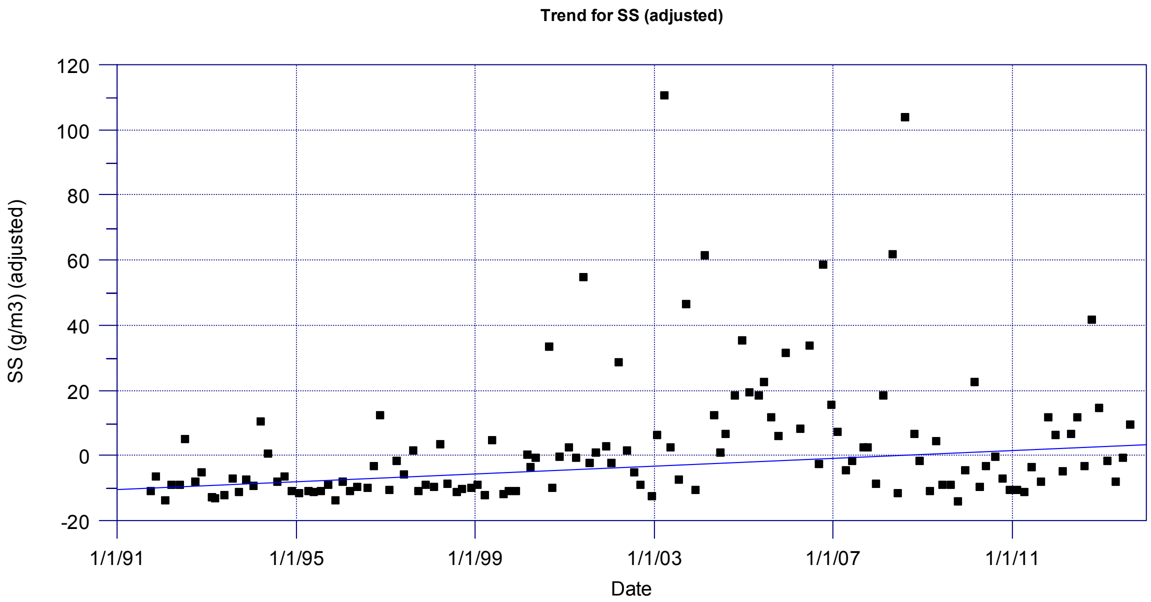


Figure 3.50 Sen slope trend for SS, Te Puna, Tauranga Harbour.

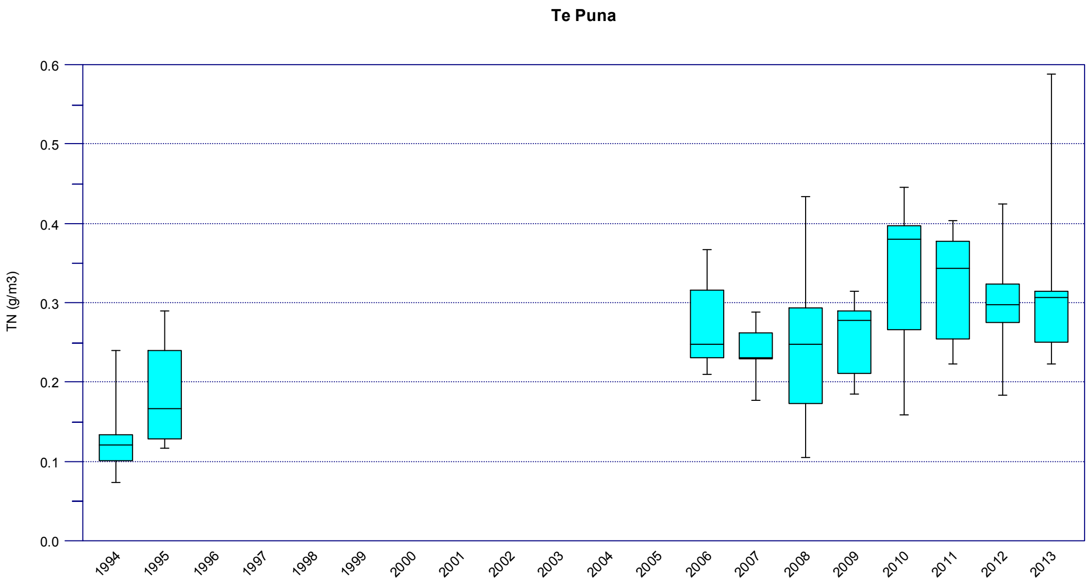


Figure 3.51 Sen slope trend for log faecal coliform, Te Puna, Tauranga Harbour.

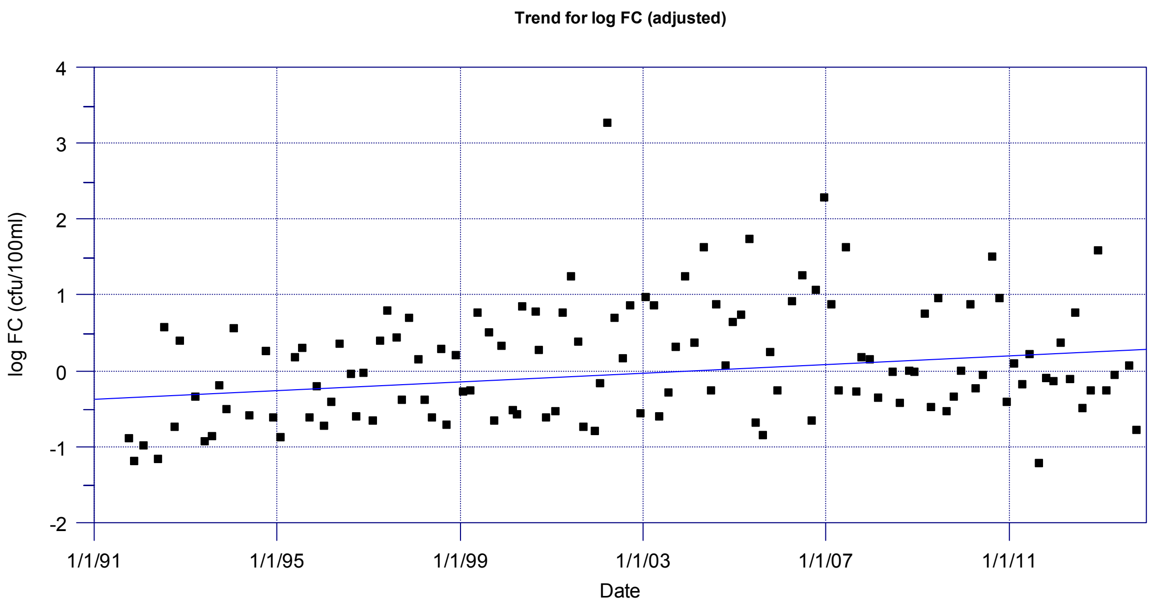


Figure 3.52 Sen slope trend for log faecal coliform, Te Puna, Tauranga Harbour.

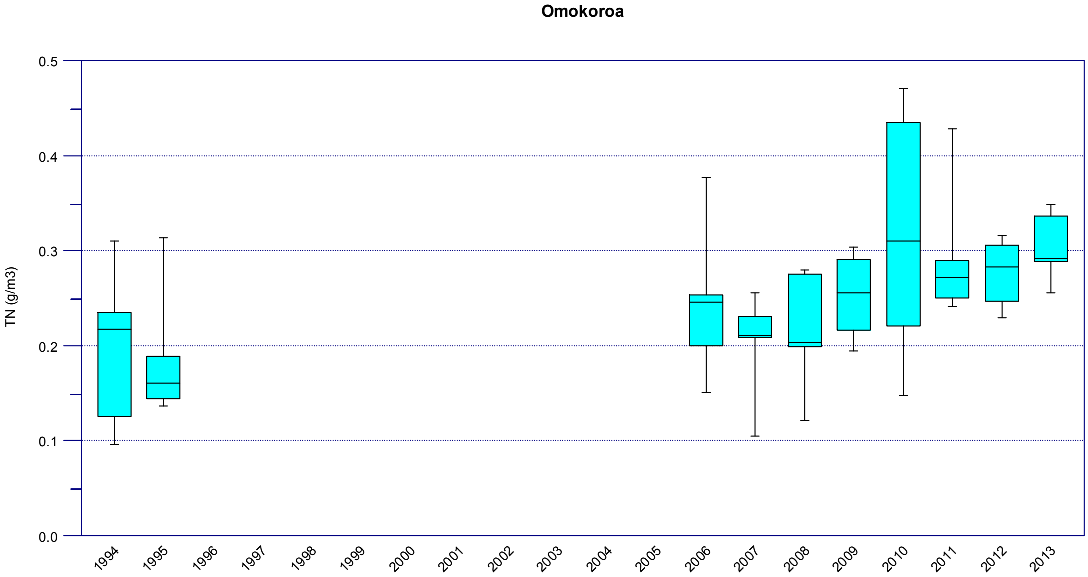


Figure 3.53 Annual medium and quartile data for TN, Te Puna and Omokoroa, Tauranga Harbour.

Table 3.19 Trend statistics for Ōmokoroa.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Omokoroa	***Trend***	▫	▫	▫	➚	➚	▫
	%/yr (RSEN)	1.21	-3.46	0.01	**1.82**	**25.1**	4.57
	Slope (10^{-3} units/yr)	167	-92	1.1	**9.5**	**16.9**	12.7

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN* (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Omokoroa	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	➚	▫	➘	➘
	% change/year	<0.01	3.01	**3.33**	3.84	**-2.27**	**-3.50**
	Slope (10^{-3} units/yr)	0.4	0.4	**0.4**	0.45	**-0.4**	**-0.02**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in Appendix 1, Table A.19, *2006-2013).

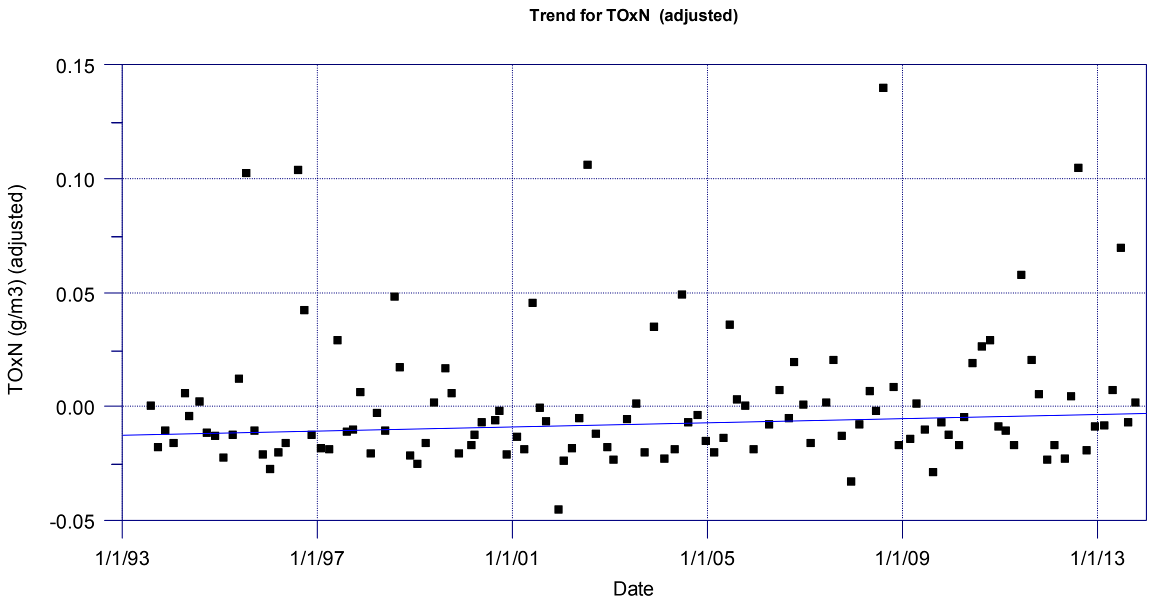


Figure 3.54 Sen slope trend for TOx-N, Omokoroa, Tauranga Harbour.

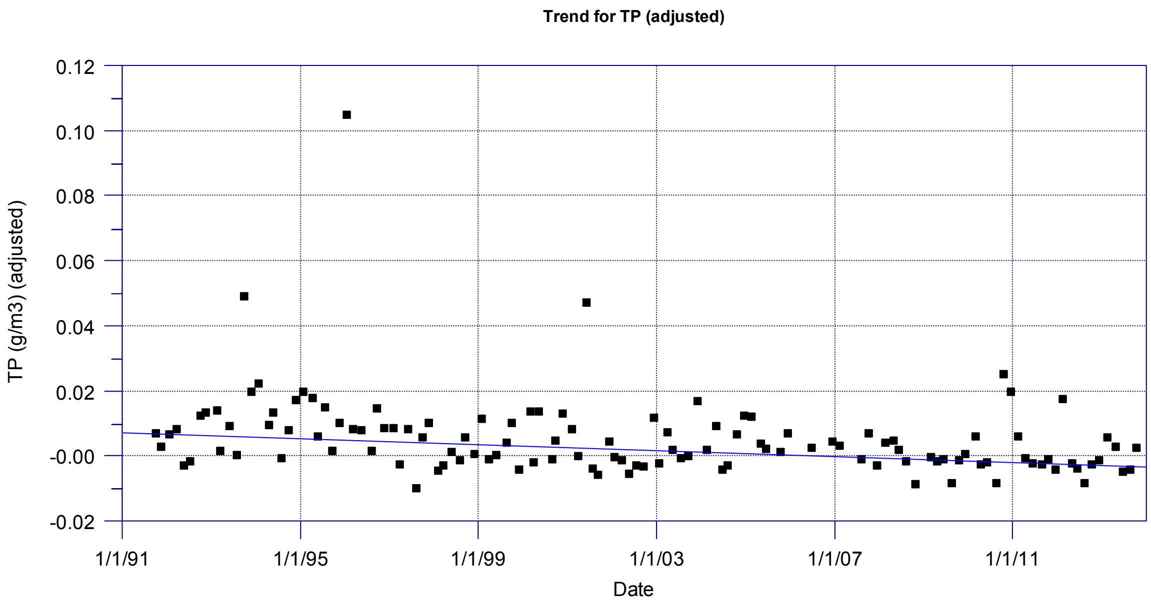


Figure 3.55 Sen slope trend for TP, Omokoroa, Tauranga Harbour.

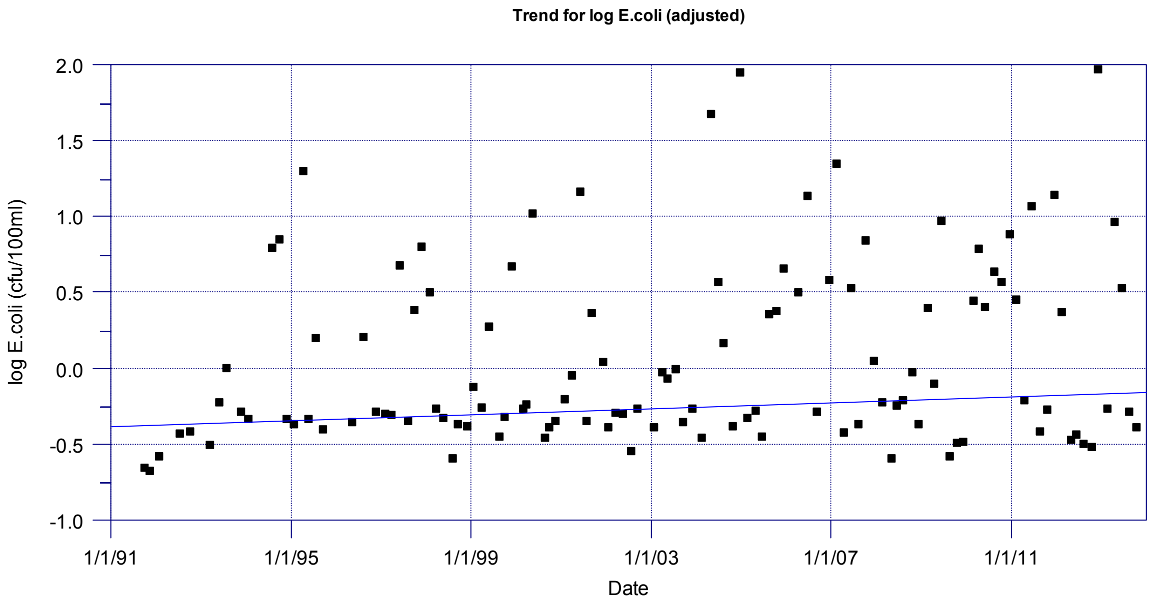


Figure 3.56 Sen slope trend for log E.coli, Omokoroa, Tauranga Harbour.

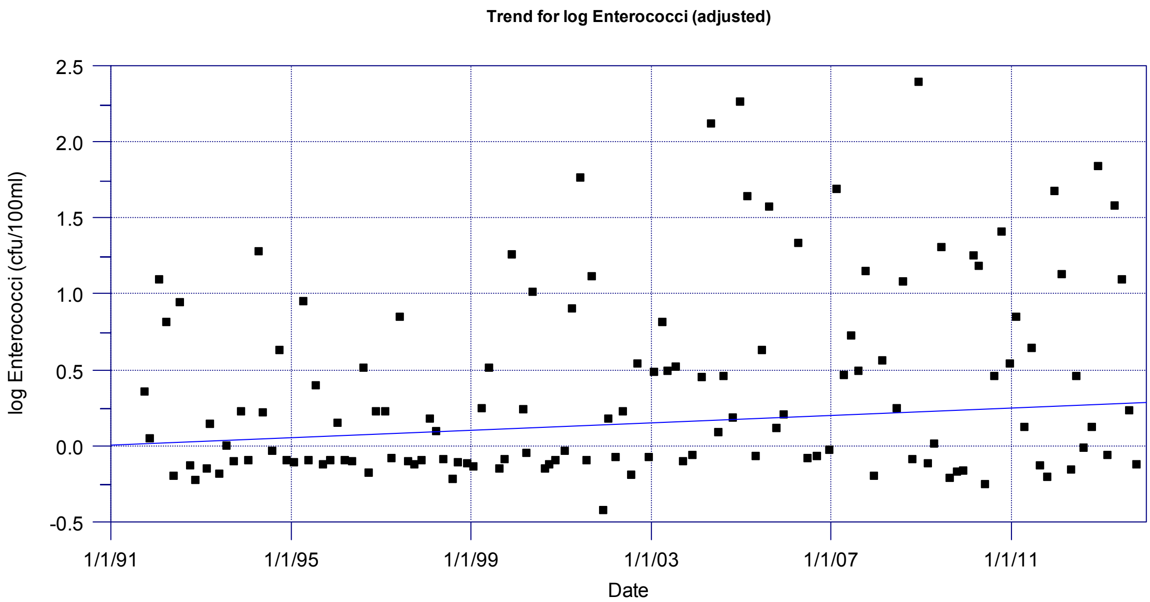


Figure 3.57 Sen slope trend for log Enterococci, Omokoroa, Tauranga Harbour.

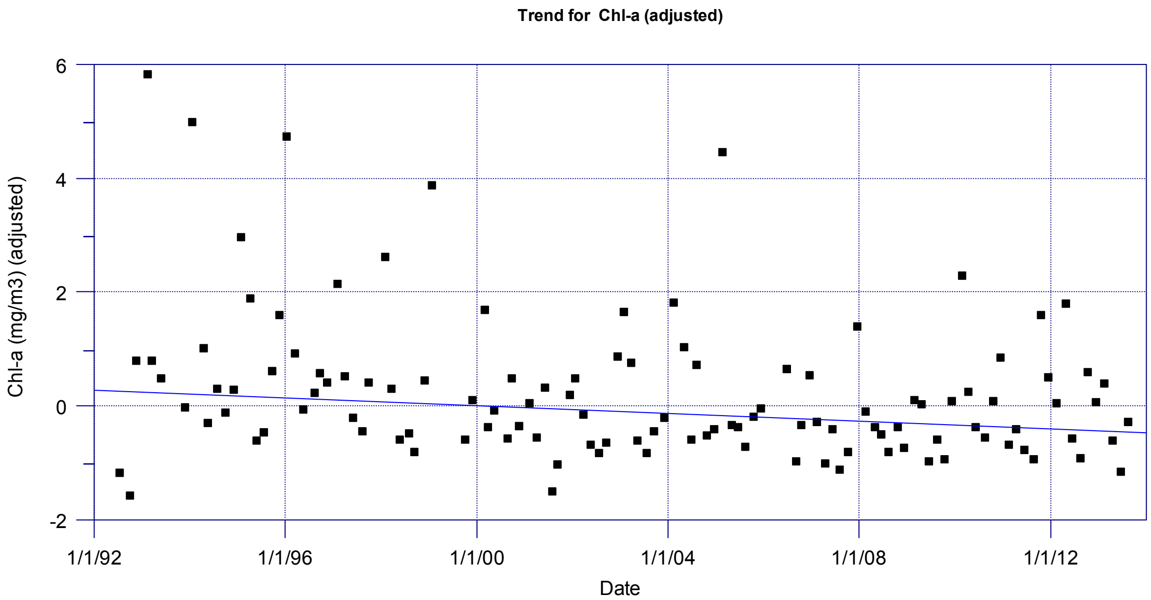


Figure 3.58 Sen slope trend for Chl-a, Omokoroa, Tauranga Harbour.

No significant trends over the full analysis period available were observed for the Pahoia site.

Table 3.20 Trend statistics for Pahoia.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Pahoia	***Trend***	▫	▫	▫	▫	▫	▫
	%/yr (RSEN)	-0.43	-2.8	0.07	-4.3	1.16	-0.22
	Slope (10^{-3} units/yr)	-92	112	0.05	23	8	-2

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN* (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Pahoia	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	▫	▫	▫	▫
	% change/year	-3.45	-0.80	3.57	2.45	0.65	1.47
	Slope (10^{-3} units/yr)	-0.1	-0.1	0.3	7	0.1	19

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in Appendix 1, Table A.20, *2004-2013).

3.9.5 North Basin trends

Current sites monitored in the North Basin include Bowentown Boat ramp, Tanners Point Jetty, and Kauri Point Jetty (Figure 2.2). Water quality statistics for each site are tabulated in Appendix 1.

Both Tanners Point and Bowentown have an increasing meaningful trend for chlorophyll-a (Figure 3.59 and 3.61), suggesting an increase in productivity in the northern estuary.

Table 3.21 Trend statistics for Kauri Point.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Kauri Point	***Trend***	□	□	□	□	□	□
	%/yr (RSEN)	1.44	-1.65	-0.03	-0.17	14.2	1.17
	Slope (10^{-3} units/yr)	246	-46	-2.3	-0.6	8.2	3

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN* (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Kauri Point	***Trend***	□	□	□	□	□	□
	% change/year	<0.01	-3.36	6.47	2.63	0.69	1.44
	Slope (10^{-3} units/yr)	<0.01	0.4	0.5	6	0.1	16.5

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time (p<0.05); ➚➘ significant and meaningful trend (p<0.05, %/yr >1%); □ not significant. (Analysis period given in Appendix 1, Table A.21, *2006-2013).

Table 3.22 Trend statistics for Tanners Point.

Site		SS (g/m³)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Tanners Point	***Trend***	□	□	□	□	□	□
	%/yr (RSEN)	-0.6	-0.76	<0.01	-1.06	16.27	-0.25
	Slope (10^{-3} units/yr)	-76	-15	<0.01	-1	10.9	-1

Site		DRP (g/m³)	NH_4-N (g/m³)	TOx-N (g/m³)	TN* (g/m³)	TP (g/m³)	Chl-a (mg/m³)
Tanners Point	***p*-value (trend slope 10^{-3} units/yr)**	□	□	□	□	□	➚
	% change/year	<0.01	-2.31	3.17	2.35	-0.76	**3.47**
	Slope (10^{-3} units/yr)	<0.01	-0.3	0.2	5.3	-0.1	**22.2**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time (p<0.05); ➚➘ significant and meaningful trend (p<0.05, %/yr >1%); □ not significant. (Analysis period given in table above; *2006-2013).

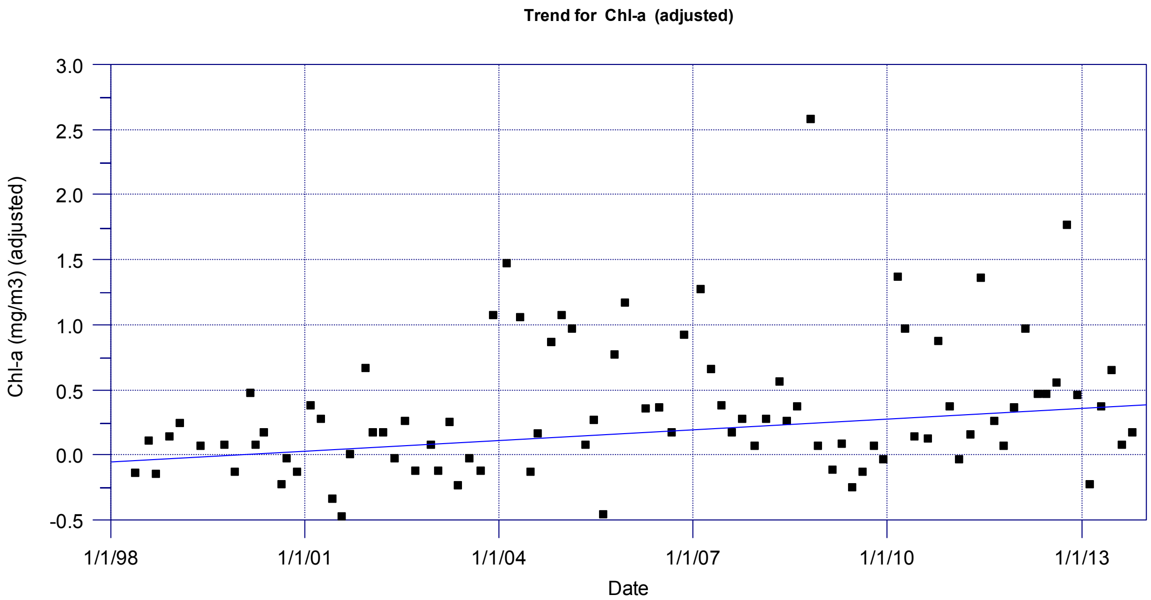


Figure 3.59 Sen slope trend for Chl-a, Tanners Point, Tauranga Harbour.

SS also shows an increasing meaningful trend at Bowentown (Figure 3.60). Again this trend is an amalgamation of episodic changes and is likely to represent a range of events from wave and wind sediment suspension to algal productivity. Unlike the southern harbour, SS shows some correlation with chlorophyll-a and TP at all three northern estuary sites hinting at differing productivity-nutrient relationship or a difference in the organic/inorganic ratio of SS.

Table 3.21 Trend statistics for Bowentown.

Site		SS (g/m^3)	Turbidity (NTU)	pH	E.coli (cfu /100 ml)	Ent (cfu /100 ml)	FC (cfu /100 ml)
Bowentown	***Trend***	➚	▫	▫	▫	▫	▫
	%/yr (RSEN)	**2.50**	-1.61	-0.04	1.77	3.16	4.06
	Slope (10^{-3} units/yr)	**258**	-22	-3.6	4	5	17

Site		DRP (g/m^3)	NH_4-N (g/m^3)	TOx-N (g/m^3)	TN* (g/m^3)	TP (g/m^3)	Chl-a (mg/m^3)
Bowentown	***p*-value (trend slope 10^{-3} units/yr)**	▫	▫	▫	▫	▫	➚
	% change/year	<0.01	-1.99	8.0	3.39	<0.01	**4.72**
	Slope (10^{-3} units/yr)	<0.01	-0.3	0.4	6.9	<0.01	**27**

Trend: ⬀⬂ significant increasing or decreasing trend of parameter over time ($p<0.05$); ➚➘ significant and meaningful trend ($p<0.05$, %/yr >1%); ▫ not significant. (Analysis period given in table above; *2006-2013).

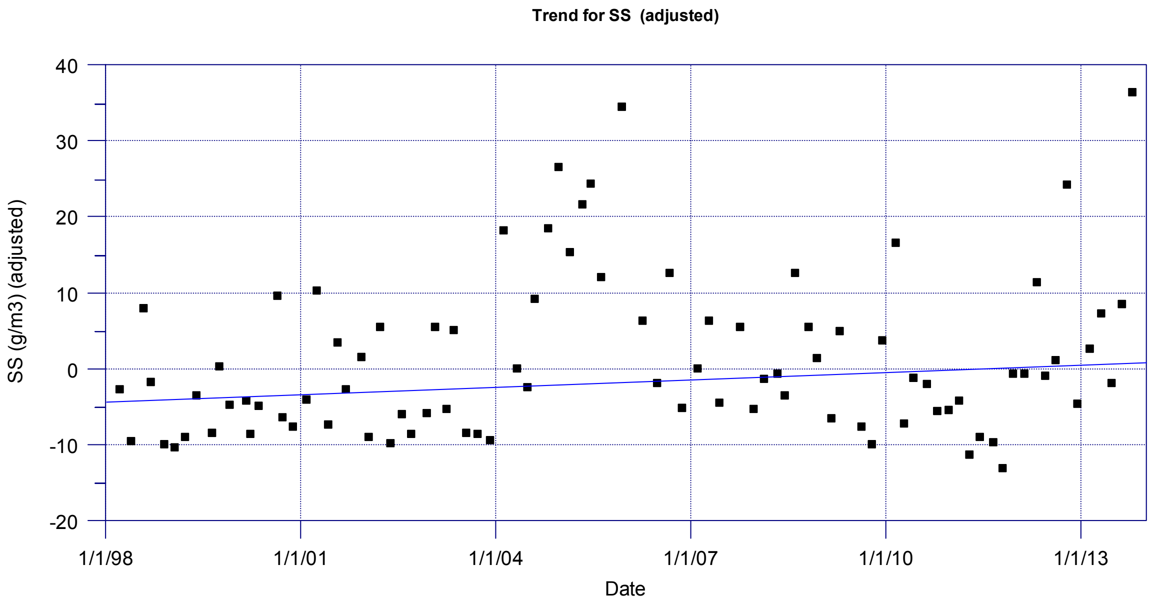


Figure 3.60 Sen slope trend for SS, Bowentown, Tauranga Harbour.

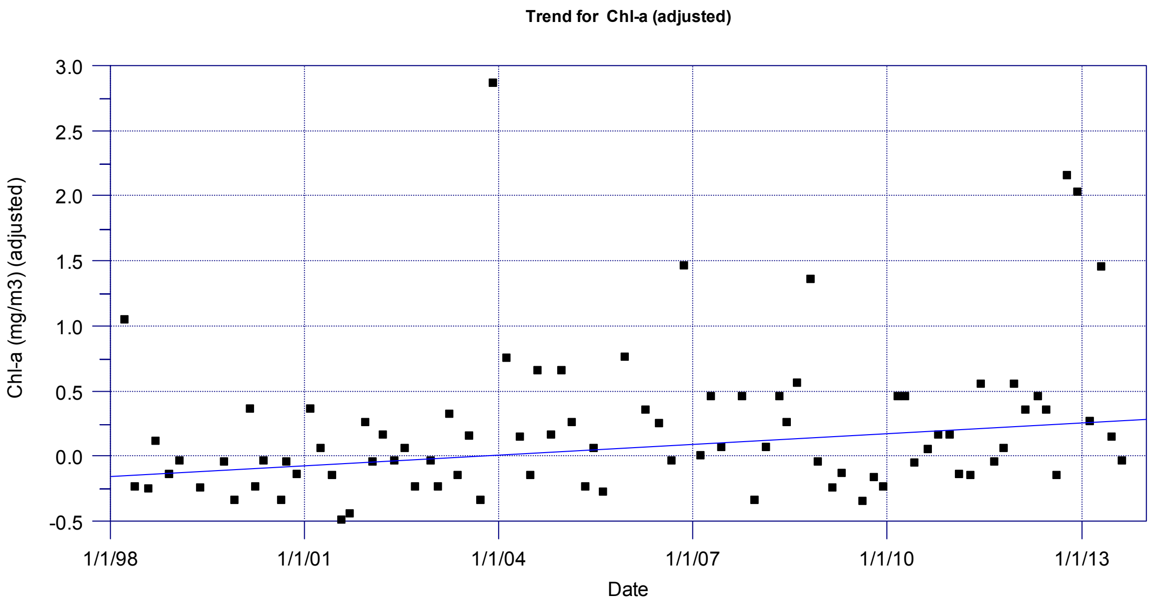


Figure 3.61 Sen slope trend for Chl-a, Bowentown, Tauranga Harbour.

Part 4: Estuary state and discussion

4.1 River estuaries

4.1.1 General water quality

River estuaries are very dynamic environments with daily tidal fluxes and frequent changes in freshwater inputs, from flood flows to drought conditions. They are traversed by 63% of our 27 native diadromous freshwater fish species and contain resident marine species, and species that migrate with the tide (McDowall, 1990). In the Bay of Plenty the river estuaries are characterised by little, if any, aquatic vegetation or macro-algae.

The water quality of river estuaries is usually dominated by freshwater creating longitudinal and vertical salinity gradients. Flood flows and the delivery of sediment and nutrients can result in these estuaries being light-limited compared to more saline waters. As a result of flood conditions and flocculation of suspended material, the Whakatāne and Ōpōtiki estuaries can accumulate fine sediment for longer compared to the well flushed u-shaped river estuaries (see flood case study). With increased sediment transport in these estuaries at times and less dilution by oceanic waters, it is no surprise that suspended solids and turbidity are more elevated compared to other estuaries (Figure 4.1).

Aquatic plants and macroalgae are typically absent in Bay of Plenty river estuaries and there is little evidence of eutrophication. Nutrients can stimulate the growth of phytoplankton (algae) and the chlorophyll-a concentration in the water is often used to give some assessment of productivity in estuaries.

The distribution of chlorophyll-a and nutrient concentrations over 2006 to 2011 are shown in Figure 4.1. Phosphorus concentrations are highest in the Tarawera and Rangitāiki estuaries, due to diffuse discharges from land activities and point source industrial discharges. Ammonium (NH_4-N) is elevated in the Kaituna relative to the other river estuaries, largely due to point source discharges, such as the Affco meat processing plant. Total oxidised nitrogen (TOx-N), mostly in the form of nitrate-nitrogen, is more concentrated in all three of these river estuaries compared to the Ōpōtiki and Whakatāne estuaries. However, they have differing changes in concentration upstream from the estuaries. Figure 4.2 shows concentrations of TOx-N with distance from the estuaries.

The Rangitāiki River is notable as it has elevated TOx-N in the upper catchment, reducing towards the estuary as the river is diluted by inputs from tributaries and due to the presence of hydro-dams which act as nitrogen sinks. The Kaituna and Tarawera Rivers are distinct from the Rangitāiki in that TOx-N increases steadily with distance down the catchment.

The Kaituna River estuary has the highest average concentration of chlorophyll-a and hence the greatest net productivity, followed closely by the Rangitāiki River estuary (Figure 4.1). Average chlorophyll-a levels in these two estuaries are below ANZECC guideline trigger levels (for south-eastern Australian estuaries), but the 75 percentiles are above this value for both estuaries. The Kaituna has had significantly higher concentrations of chlorophyll-a driven by an increase in cyano-bacterial blooms in recent years. These algal blooms are seeded predominantly from Lake Rotorua and have subsided in the last few years as lake water quality has improved. This has led to decrease chlorophyll-a concentrations being below the 4 mg/m^3 trigger from 2011 to present.

The Rangitāiki estuary has also experienced some sewage fungus growth (*Sphaerotilus*) as a result of lactose in the Fonterra Dairy Factory discharge. Sewage fungus is typically devoid of chlorophyll, but other species of periphyton such as potentially toxic benthic mat forming species (e.g. *Phormidium*) also occur periodically in the river. However, it is likely that much of the phytoplankton biomass found in the estuary is from open coastal species of diatoms and dinoflagellates (*pers comm* Stephen Park). Any blooms of these are likely to be very short lived due to the low residence times of saltwater in the estuary.

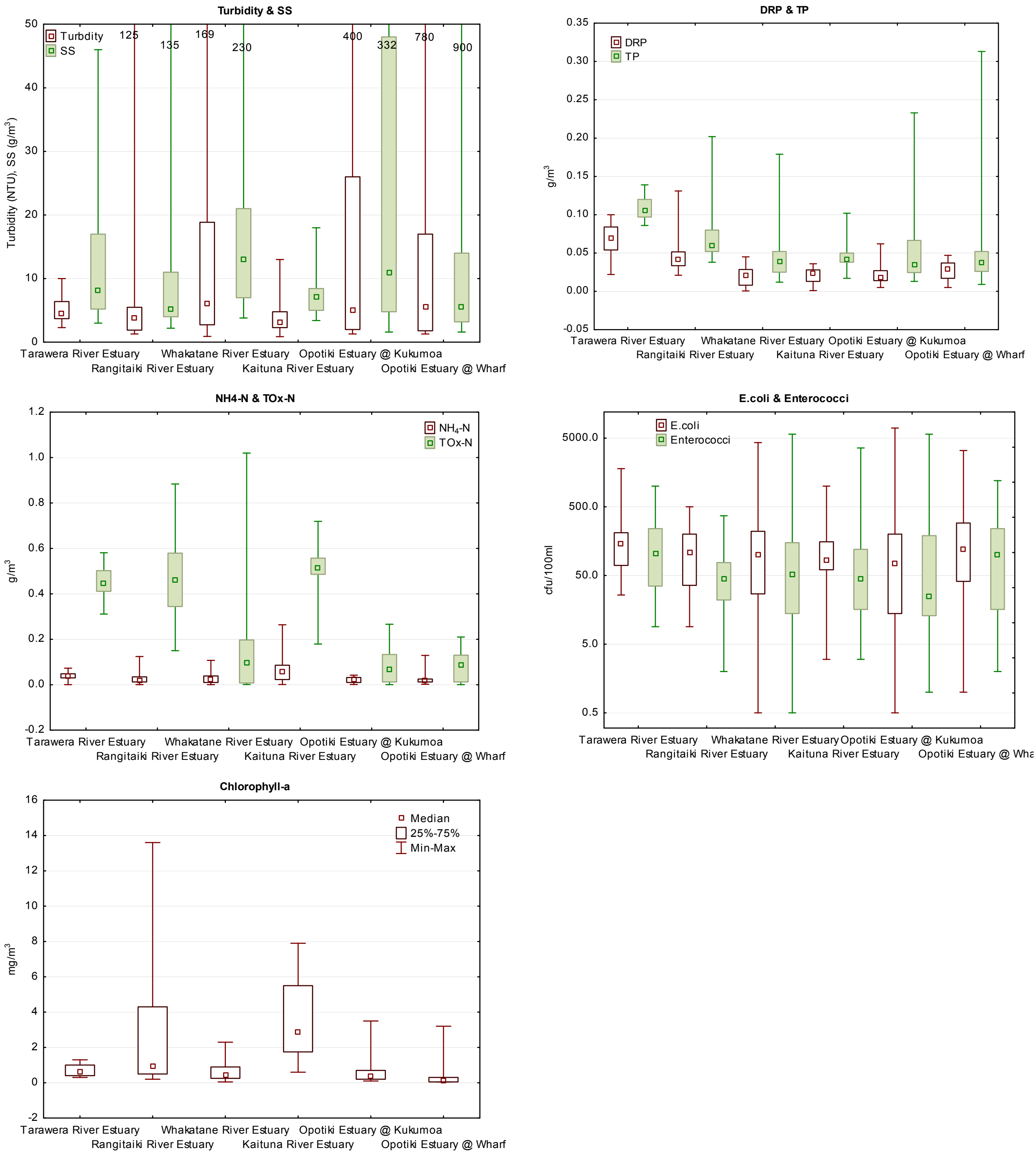


Figure 4.1 Box whisker plots for River estuary parameters, 2006-2011 (Median, interquartile range, min and max shown).

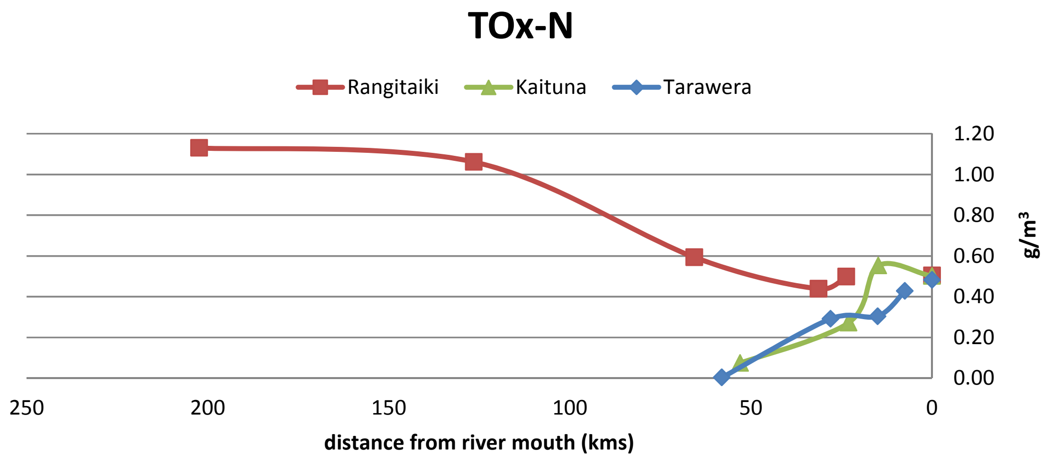


Figure 4.2 Concentration of TOx-N with distance from river mouth, 2010-2013.

An understanding of the nutrient limiting plant growth is important when attempting to manage eutrophication. The relationships between chlorophyll-a, dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are shown in Figure 4.3 for the riverine estuaries, these show the following:

- The Kaituna River estuary has a high DIN:DRP ratio (~30) which suggests phosphorus is limiting phytoplankton growth (EPA, 2001). However, there does seem to be some response of chlorophyll-a to increasing DIN, although it seems clear that luxury (storage) uptake of DRP occurs with increasing phytoplankton productivity.
- In the Rangitāiki River estuary phytoplankton appear to be more co-limited in terms of nutrients.
- In the Tarawera River estuary the DIN:DRP ratio suggests nitrogen limitation. With little response in chlorophyll-a to either nutrient other factors such as light limitation are likely to be limiting phytoplankton growth. The euphotic depth (the depth at which 99% of surface light is extinguished in the water column) in the Tarawera Estuary has improved from around 1.8 m in 2003 to an average of almost 3.0 m in 2012, although no statistical increase in chlorophyll-a has been observed.
- A trend of increasing chlorophyll-a was observed in the Ōpōtiki estuary (at Kukumoa). This estuary has a DIN:DRP ratio that suggests nitrogen limitation, but as chlorophyll-a concentrations are generally well below ANZECC guideline trigger levels it seems unlikely that the increased productivity is causing any undue ecological stress in the estuary.

It is not clear if occasional periods of elevated productivity (> 4.0 mg Chlorophyll-a/m^3) are having negative impacts in the riverine estuaries. In the Kaituna River there has been risk to human and stock health due to toxin producing cyano-bacteria, however the impacts on the estuarine ecology is not clear.

Because riverine estuaries are at the bottom of river catchments they are vulnerable to faecal contamination events which occur due to rainfall events. *E.coli* are the preferred indicator of faecal contamination risk to human health in many of the riverine estuaries due to the low salinity (generally oligohaline with salinity at 0-5 ppt). For saline waters enterococci are the preferred indicator of faecal contamination and while these may be more relevant to the Whakatāne and Ōpōtiki estuaries the levels of *E.coli* and Enterococci are not significantly different (Figure 4.1). Over the period 2006 to 2011 all but one of the river estuaries exceeded the Microbiological Guideline red alert mode (*E.coli* greater than 550 cfu/100 ml) on at least one occasion. The median *E.coli* levels for all estuaries were well below the orange alert level (260 cfu/100 ml) indicating that the estuaries are generally safe for contact recreation.

In the Tarawera River estuary both *E.coli* and faecal coliform concentrations have decreased, this is likely due to improvements in discharges from municipal sewage treatment plants.

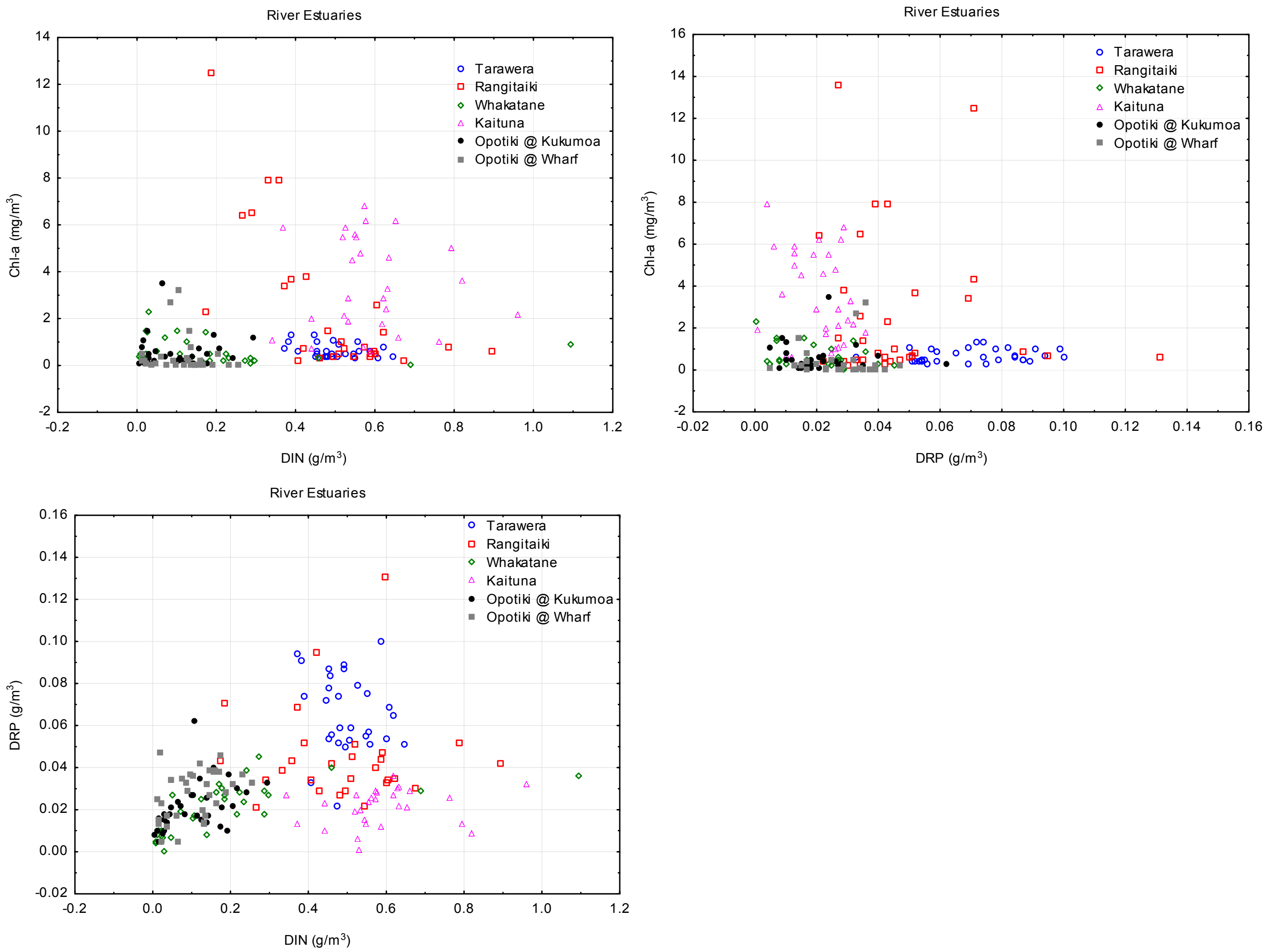


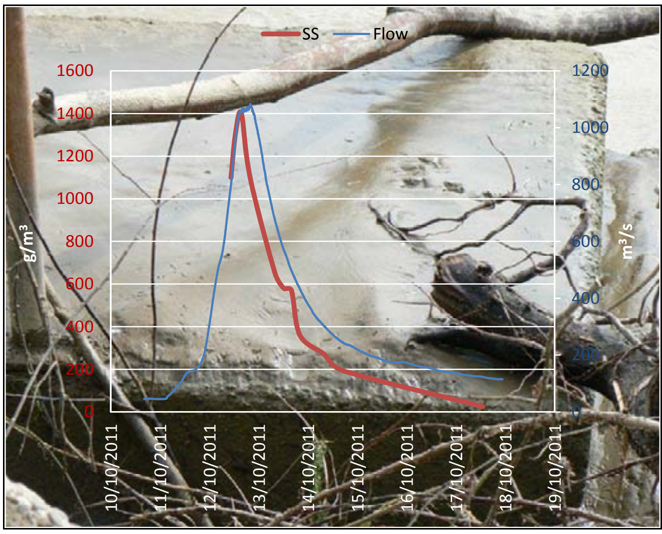
Figure 4.3 Chlorophyll-a versus dissolved nutrient concentrations, and DRP versus DIN, river estuaries, 2006-2011.

A number of rivers are monitored for microbiological quality during the bathing season (spring/summer) at sites immediately above the estuarine sampling sites. In 2013 the Otara and Waioeka Rivers were given ‘suitability for recreation grades’ (SFRGs) of ‘Fair’ and ‘Poor respectively. The Whakatāne was graded ‘Very Poor’ at the top end of the estuary and ‘Fair’ at the bottom, while the Kaituna at Waitangi was graded ‘Fair’. These results reflect the impacts of a range of activities including pastoral and urban land use, and industrial discharges.

4.1.2 Sediment discharges: Whakatāne Estuary case study

Storm events have the ability to wash large amounts of sediment from the catchment to estuaries and ultimately the ocean. Before arriving at the ocean freshwater laden with sediment must pass through the estuarine environment. In flood flows sediment is deposited in low energy zones such as on river banks and sand banks. Sedimentation in estuaries is also enhanced as estuary circulation patterns introduce saline waters to fresh. When the tide ebbs estuarine muds can be eroded, decreasing water clarity and reducing light penetration through the water column.

The photos below illustrate fresh sediment deposited in low energy zones after a flood event in the Whakatāne Estuary. Figure 4.4a show the flow record and sediment concentrations in the estuary during the flood event, and 4.4b shows the sediment discharge through the estuary. In October 2010, around 10,000 tonnes of sediment flowed through the estuary over four hours at the floods peak.



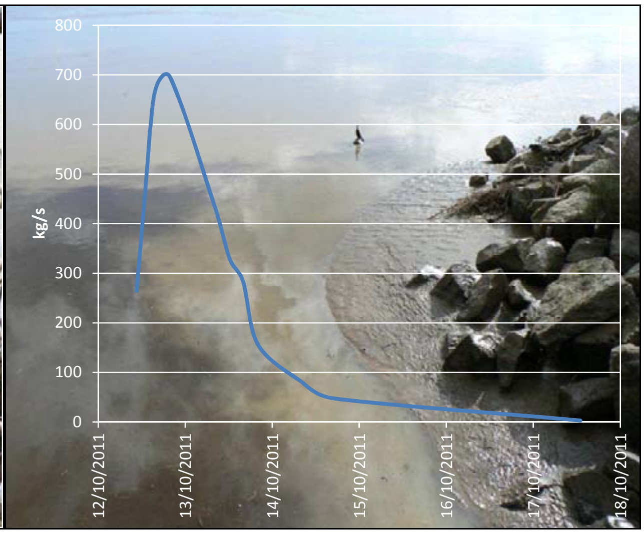


Figure 4.4 a) SS concentration in the Whakatāne Estuary and flow measured at Taneatua Road; b) Estimated SS load at Whakatāne Estuary.

4.2 Eastern and central estuaries

Three estuaries described in this section are tidal lagoons of moderate size and these have lower levels of fresh water influence. All of these estuaries have one dominant freshwater input and over 70% of their intertidal area is exposed sand and mudflats at low tide.

Ōhiwa Harbour marks the southern extent of mangroves (*Avicennia marina var. australasica*) and these have increased in areal extent 6-fold since 1945 (MacKenzie, 2013). Compared to the almost 120 ha of mangrove area at Ōhiwa, the 6.5 ha at Waihī Estuary represents only a small percentage (<2%) of the estuary while Maketū Estuary has only a few sparse mangrove bushes. Other aquatic vegetation in these estuaries includes sea grass (*Zostera muelleri*) which in in 2011 was around 100 ha in extent in Ōhiwa harbour, 1.14 ha in Waihī Estuary and 0.004 ha in Maketū. Of concern is the recent appearance of nuisance levels of the macro-algae *Gracilaria chilensis* in the Waihī and Maketū Estuaries, this species has also been found previously in Ōhiwa Harbour (pers comm. Wendy Nelson, NIWA).

All of these estuaries have relatively high average suspended sediment concentrations (Figure 4.5) compared to the river estuaries. Increased sediment trapping is expected given these estuaries have shallow depth and smaller net ebb-transport energy - these factors mean they are more susceptible to the impacts of sediment re-suspension with flood flows, wind and wave action than in deeper and better flushed estuaries. While sediment and particulate matter can smother benthic communities and transports nutrients and other pollutants, the distribution of these materials is essential to the biological productivity of estuarine systems (Pierson *et al*, 2002).

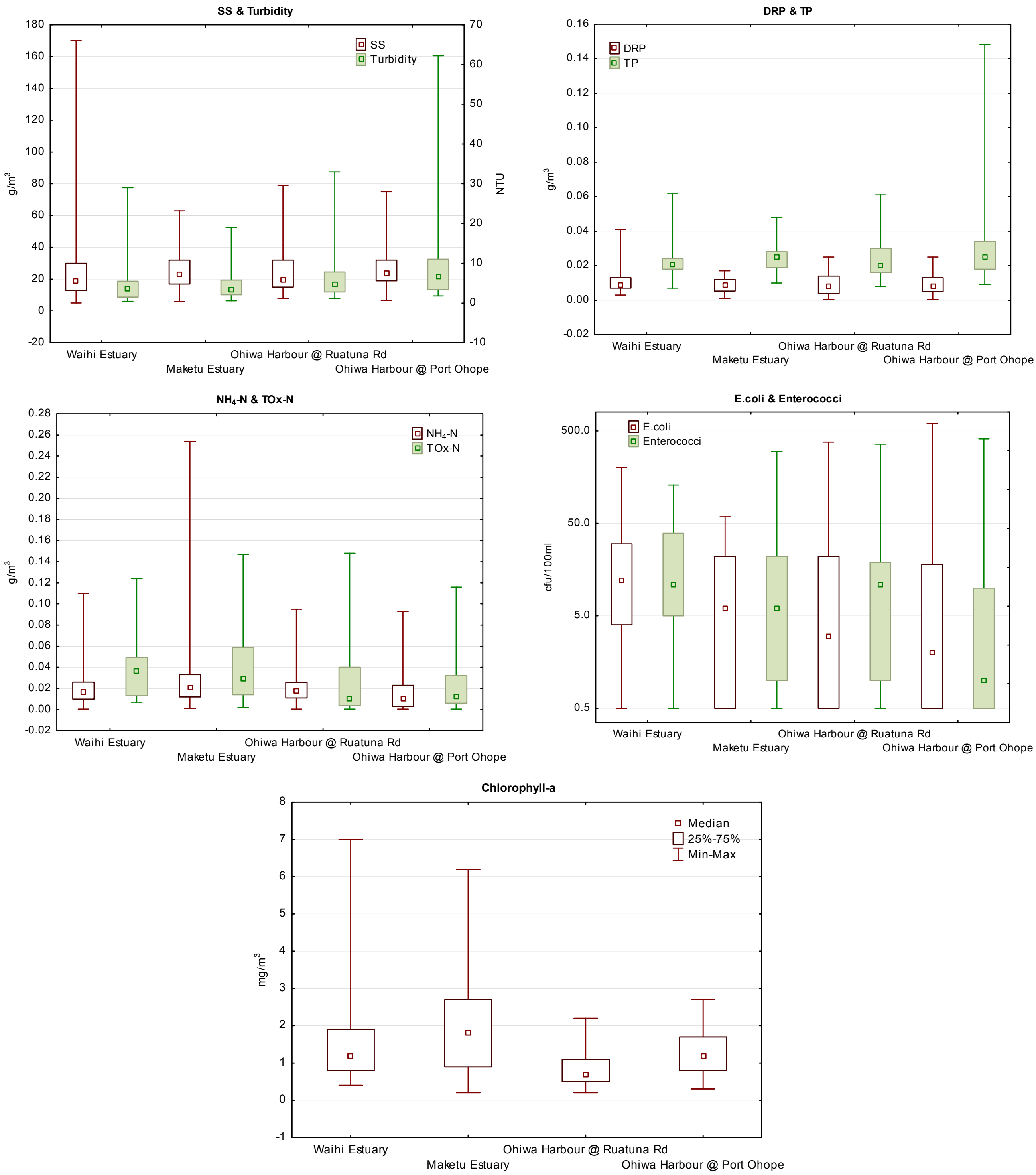


Figure 4.5 Box whisker plots for eastern and central estuaries, 2006-2011.

The average turbidity for these three estuaries (2006-2011) is below the 10 NTU ANZECC (2000) trigger level. Ōhiwa at Port Ōhope has the highest average turbidity (6.8 NTU over the period) and the highest maximum (63 NTU compared to less than 35 NTU for the other two estuaries). High turbidity can result from severe weather events which cause erosion of clay soils around Ōhiwa Harbour – these leave a thin layer of silt and clay across the harbour. Some sites in Ōhiwa have exhibited an increase in mud (very fine clay and silt particles) and while with benthic macrofauna species have remained stable sponges in some areas are decreasing (Park, 2012).

Two sites (Port Ōhope and Maketū) have increasing trends in SS but not in turbidity (see Table 5.2, Part 5). This may in part be explained by the stronger correlation of chlorophyll-a (phytoplankton) with turbidity, than with SS. Phytoplankton concentrations can be reduced with increasing SS concentrations due to light limitation and increased freshwater flushing. As turbidity can increase with phytoplankton growth, ratios of organic to inorganic suspended solids vary, hence the difference in trends. Increasing trends in SS are potentially climatically driven dependant reflecting increases in wind speed, and corresponding increasing in wave action in the estuaries.

Port Ōhope also has the highest average SS and TP levels with these two parameters being weakly correlated. Average TP levels for all estuaries are below the ANZECC (2000) trigger levels (0.03 g/m^3) however Port Ōhope levels exceed this around 25% of the time. Soluble phosphorus, as shown by DRP concentrations (Figure 4.5), is similar for all estuaries. Ōhiwa Harbour sites have higher concentrations of DRP in winter reflecting the lack of uptake by algae during the cooler winter months.

Maketū Estuary had the highest average and highest maximum ammonium concentrations of these three estuaries over the 2006 to 2011 period (Figure 4.5), as well as strong recent increases in TN. Average ammonium concentrations are above the ANZECC (2000) trigger level (0.015 g/m^3) for slightly disturbed estuarine ecosystems. TOx-N average concentrations are also above the ANZECC (2000) trigger level in Waihī and Maketū Estuaries which is a feature of their more dominant freshwater input compared to
Ōhiwa Harbour. The higher nutrient concentrations in these two estuaries partly explains the higher chlorophyll-a concentrations compared to Ōhiwa. In the Waihī Estuary there is a strong correlation between DIN and DRP (Pearson R=0.707, p=0.01) further indicating the influence of the freshwater input on the estuarine system. Verification of how much nutrient is coming into the estuary from freshwater sources is required.

The high proportion of freshwater inputs also explains why the Waihī Estuary has the highest average indicator bacteria results of the three estuaries. All three estuaries had only had a few occasions where indicator bacteria results were above microbiological water quality guidelines, with all sites being below the guideline levels 95% of the time.

4.2.1 Tauranga Harbour

Tauranga Harbour is largely composed of tidal flats (66% of area) with large intertidal flats in the centre of the harbour separating the north from the south. Deep channels are maintained by tidal ebb and flood flows and water quality is influenced by a mix of oceanic and fresh water.

Research has identified that nutrients, heavy metals and sediment are key factors affecting the ecology of the harbour (Ellis *et. al*, 2013; Park, 2003; Park 2011). While there is some indication that nitrogen is increasing in the harbour, phosphorus appears to be decreasing. The implications of this are not yet well understood, particularly with respect to the factors causing nuisance growths of sea lettuce.

It is clear that the sub-estuaries, particularly those further away from the harbour entrance, are more likely to accumulate sediments and contaminants (Tay *et al*, 2013). It is in these areas that benthic macrofauna have been found to be negatively impacted as determined by species response curves (Ellis *et. al*, 2013), although long-term monitoring has shown no significant increase or decrease in species diversity (Park, 2012). However, more sensitive areas in sub-tidal reaches may differ in their ecological responses.

Comparisons of several water quality parameters at 11 sites in Tauranga Harbour are presented in Figure 4.6 for the period 2006 to 2011. The highest average SS concentrations are found at Pahoia, Otumoetai (high tide site) and Te Puna - all of these sites are located in shallow inter-tidal flats. Turbidity shows the same pattern - the highest average turbidity was recorded at Pahoia which is the site within the southern harbour receiving the least amount of tidal flushing. Sub-estuaries and/or areas further from the harbour entrance have higher residence times and are therefore more likely to accumulate sediments and contaminants (Tay *et al*., 2013) and also have greater silt and clay content in the sediments. Silt and clay are more easily entrained in the water column (Pritchard *et al*, 2009) and therefore these areas are more likely to have higher SS and turbidity. Turbidity and SS maximums were highest in the southern basin at Pahoia, Te Puna and Ōmokoroa and this is most likely due to higher residence times, the influence of the Wairoa River, and sediment disturbance from wind and wave action.

Turbidity levels above the ANZECC (2000) guideline of 10 NTU were recorded at five of the 11 sites in the harbour, however the 75th percentile was below this level for all sites indicating that the overall water clarity is good. Low tide turbidity was on average higher than 10 NTU (see Tables A.14 and A.16) showing the impact of entrained sediment as water drains from the mud flats.

Light limitation can be a factor in the reduction of sea grass (*Zostera muelleri*) beds in the harbour, along with eutrophication, swan grazing, sedimentation, human impacts (e.g. dredging), and storm damage. Sea grass is an indicator of good ecological health and declined by 34% in Tauranga Harbour over the period 1959 to 1996 (Park, 1999), although there are signs that it is recovering in some areas (Sinner *et al*., 2011). Given the turbidity results reported here and some limited water clarity data it would seem unlikely that light limitation has been a significant factor for sea grass beds recently, however monitoring may not be picking up episodic light limiting events such as might occur following intense storm events.

Water column total phosphorous concentrations were highest at Kauri Point and Maungatapu, however the median values were under the 30 mg/m^3 ANZECC guideline value. DRP was also highest at Maungatapu.

On average dissolved inorganic nitrogen (TOx-N and NH_4-N) are above the ANZECC (2000) guideline value (0.015 g/m^3). This guideline may not be appropriate for Bay of Plenty estuaries given that oceanic waters are of a similar average concentration for dissolved nitrogen, particularly for TOx-N. Figure 4.8 shows surface water dissolved inorganic nitrogen concentrations over increasing depths, and while harbour waters have higher concentrations as might be expected, oceanic waters can also be near or over the ANZECC trigger value.

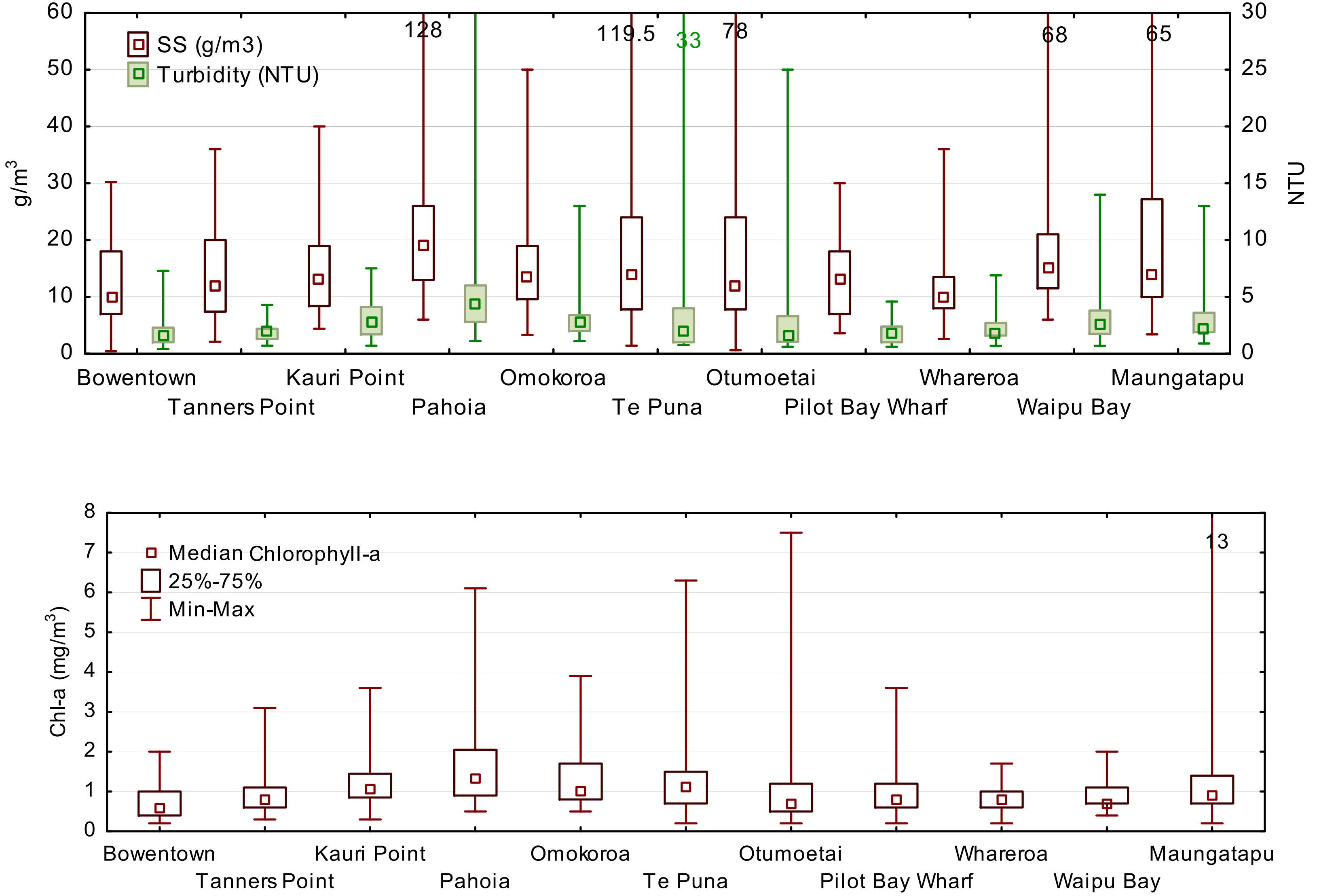


Figure 4.6 Box whisker plots for SS, turbidity and chlorophyll-a at Tauranga Harbour sites, 2006-2011.

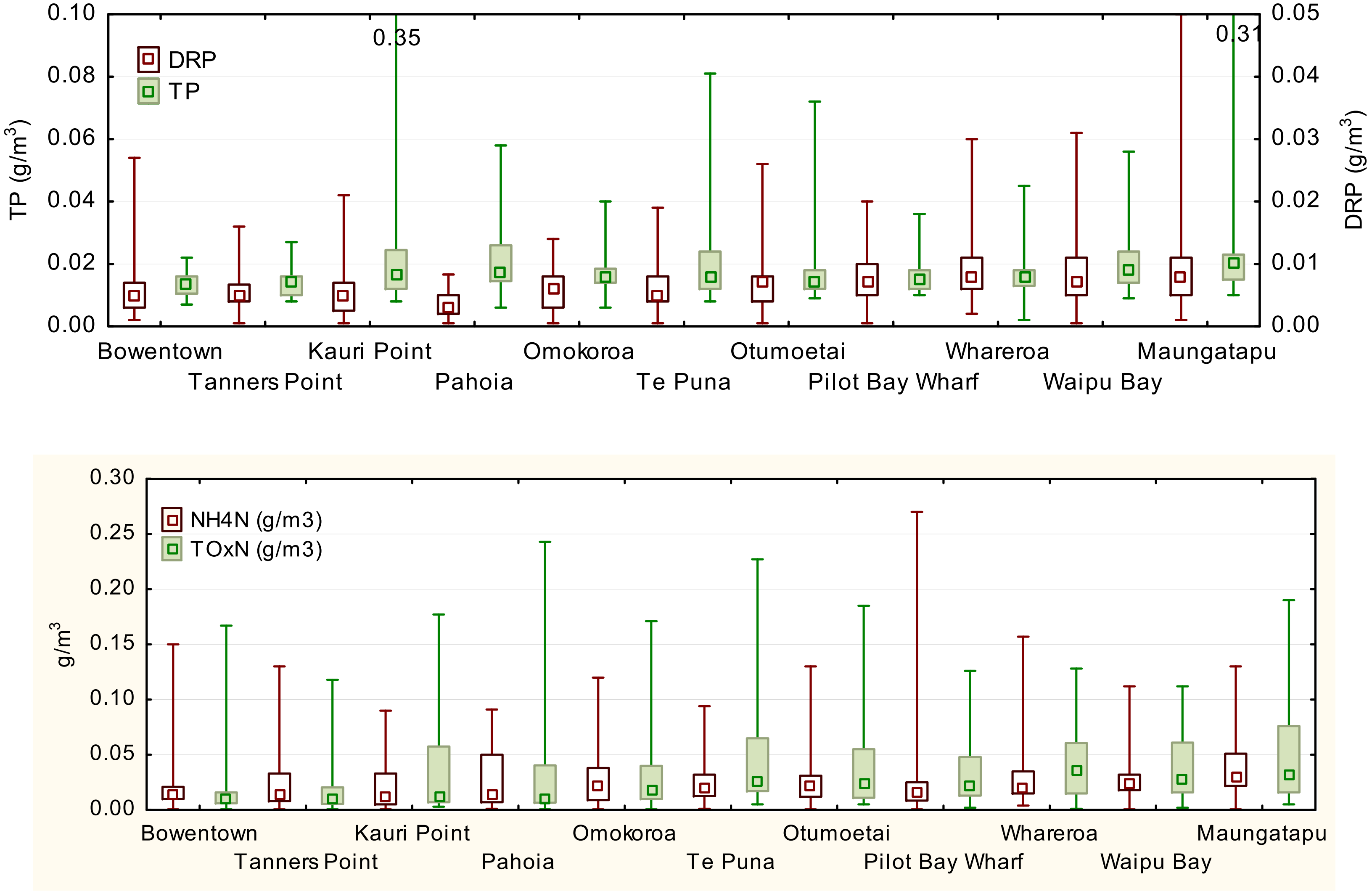


Figure 4.7 Box whisker plots for TP, DRP, NH_4-N and TOx-N at Tauranga Harbour sites, 2006-2011.

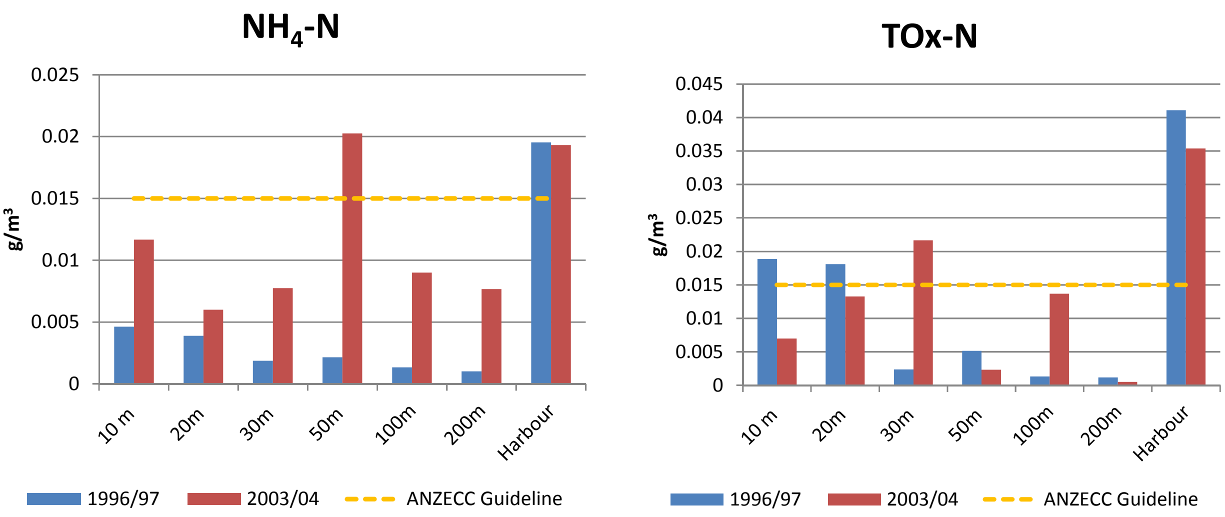


Figure 4.8 *NH_4-N and TOxN average concentrations for Tauranga transects (96/97) and Pukehina transects (03/04) in oceanic surface waters at differing depths away from land, and average Tauranga Harbour concentrations over a range of sites for the same time periods.*

DIN shows strong seasonal peaks (Figure 4.9) reflecting freshwater inputs, seasonal upwelling of nutrients in oceanic waters (Park, 2005), and nutrient uptake by plants and algae during late spring-summer. Maungatapu and Whareroa had the highest average dissolved inorganic nitrogen concentrations (Figure 4.7). However chlorophyll-a at Whareroa was amongst the lowest recorded (Figure 4.6) - this lower productivity (and therefore potentially lower nutrient uptake) may explain the higher DIN concentrations at this site. The median chlorophyll-a concentration at Maungatapu is not quite as low as Wharaeroa, but it is lower than most other sites in the southern part of the harbour.

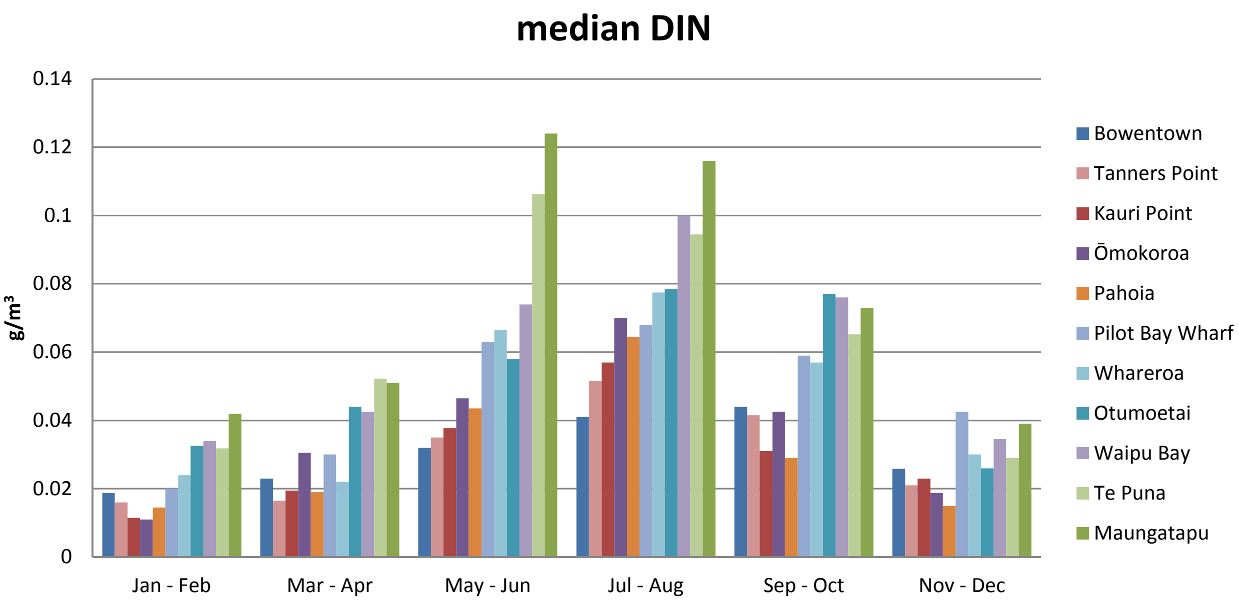


Figure 4.9 *Seasonal median DIN concentrations in Tauranga Harbour, 1998-2013.*

Pahoia is some distance from the harbour entrance and has the highest median chlorophyll-a concentrations followed closely by its northern counterpart, Kauri Point. The spring-summer concentrations of DRP are lowest at these sites suggesting that phytoplankton and macro-algae production is limited by the uptake of phosphorus, and that growing conditions are better in the upper reaches of the harbour. It is of interest that no correlation was found between sediment chlorophyll-a and sediment nutrient concentrations at 75 sites sampled by Ellis *et al.* (2013) in the summer of 2011/2012. Dissolved oxygen concentrations can also show a strong negative correlation with DRP at some sites, such as Pahoia. Lower DRP concentrations may limit productivity, and reduced phytoplankton and macro-algae respiration could be one factor impacting the dissolved oxygen content of the water column. Sea lettuce (*Ulva* spp.*)* is a potentially significant sink of nutrients and on decomposition can also reduce oxygen levels.

Faecal indicator bacteria results show that the recreational water quality of Tauranga Harbour is good (Figure 4.10). Concentrations of faecal bacteria do occasionally exceed the Microbiological Guidelines and these instances are often associated with rainfall or one-off contamination events (e.g. sewage overflows). The highest enterococci levels occurred in the Northern Harbour at Bowentown and Kauri Point, while *E.coli* were highest at Te Puna and Whareroa). Most sites have a significant positive correlation of *E.coli* versus enterococci (Pearson R = 0.36-0.60, p<0.01), although Maungatapu has a negative correlation (Pearson R = -0.42, p<0.01). At Maungatapu, *E.coli* does have an unusual positive relationship with conductivity (Pearson R =0.35, p<0.01), possibly indicating a dominant source on the incoming tide.

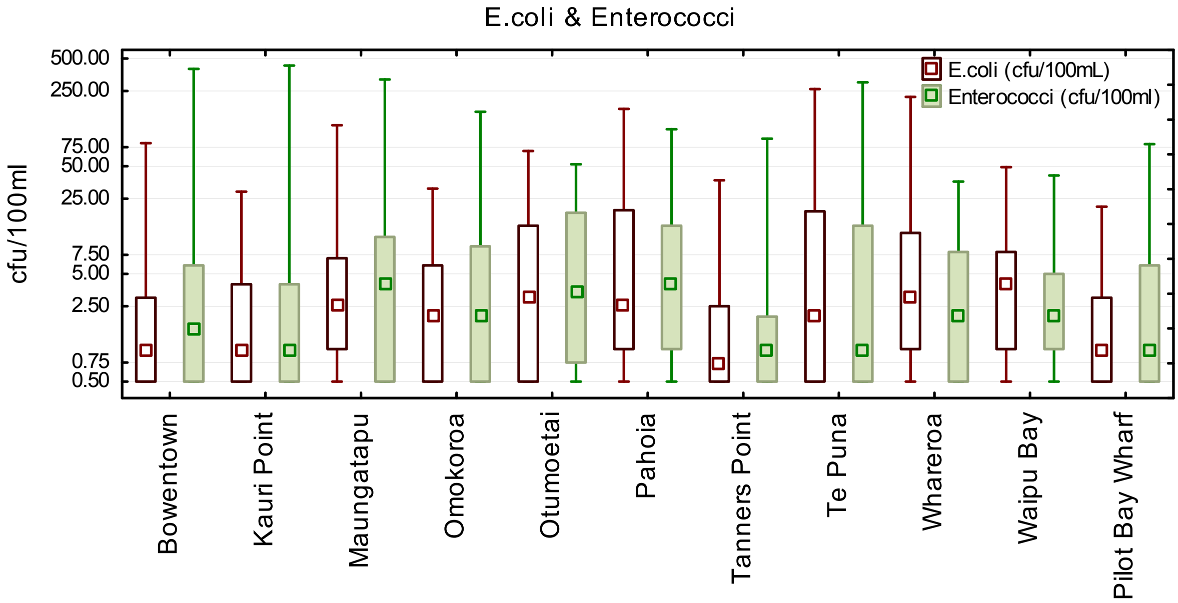


Figure 4.10 Indicator bacteria box whisker plots for Tauranga Harbour sites, 2006-2011.

Both low tide sites (Kumlin Ave, Otumoetai and Grace Street) show decreasing trends for *E.coli*, however Ōmokoroa, Te Puna and Otumoetai have increasing trends for indicator bacteria. These three high tide sites are influenced by the Wairoa River which itself has increasing trends for faecal indicator bacteria. Weak negative correlations of indicator bacteria (and nitrogen) versus conductivity indicate the influence of this freshwater input.

Part 5: Summary and conclusions

The following summarises water quality state and trends in the Bay of Plenty estuaries. Where appropriate the data is also compared against the Water Quality Classifications in the Regional Coastal Environment Plan (although note that these classifications are used to assess the impacts of discharges and therefore may not be relevant in all cases).

5.1 River estuaries

Meaningful trends are apparent for a number of the river estuaries, these are summarised in Table 5.1 below.

Table 5.1 Water quality trends river estuaries.

Sites	Suspended solids	Turbidity*	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Chlorophyll-a	Analysis Period
Ōpōtiki at Wharf			▼			▲						1995 – 2013
Ōpōtiki at Kukomoa			▼			▲				▽	▲	1990 – 2013
Whakatāne		▼										1995 – 2013
Rangitāiki				▲		▲	▲					1995 – 2013
Tarawera	▼	▼	▼	▲				▼		▼		1995 – 2013
Kaituna		▼	▼	▲		▲			▲		▼	1990 – 2013

▲ = meaningful increase; △ = significant increase; ▼ = meaningful decrease; ▽ = significant decrease; na = not analysed. * analysed from 1996.

5.1.1 Ōpōtiki River Estuary summary

- Low nutrient status and productivity compared to some other Bay of Plenty river estuaries.
- Decreasing ammonium but increasing dissolved reactive phosphorus, possibly leading to a slight increase in productivity (e.g. at Kukumoa).
- An increase in pH seen at lower (Wharf) site, but pH is still well within expected levels.
- Saturated dissolved oxygen levels have at times been below 80% in the last five years.
- Faecal coliform have declined. Enterococci indicate that recreational water quality guidelines are on occasion exceeded, usually during high river flow conditions.

5.1.2 Whakatāne River Estuary

- Trend of decreasing turbidity. The estuary has higher turbidity and suspended solids concentrations than the other river estuaries, primarily due to its geological setting.

- Indicator bacteria are showing an increase but this is not statistically significant. Enterococci are occasionally above recreational guidelines - this is generally driven by high river flow.
- Dissolved inorganic nitrogen is low compared to rivers estuaries dominated by volcanic sediments.

5.1.3 Rangitāiki River Estuary

- Increasing nitrate-nitrogen in the upper river catchment is also apparent in the estuary.
- Phosphorus shows an increasing trend in the estuary but this is not seen in the river above Edgecumbe. This may be due to land use activities in the lower catchment.
- The Rangitāiki Estuary has the highest maximum chlorophyll-a levels and the second highest median of the river estuaries, corresponding to elevated nutrient levels.
- Microbiological water quality is graded as good with indicator bacteria levels rarely exceeding ‘red alert’ mode.

5.1.4 Tarawera River Estuary

- Improving trends in turbidity suspended solids, and dissolved oxygen - this is largely due to improvements in industrial discharges.
- Nitrate-nitrogen shows an increasing trend, although levels have decreased in recent years.
- Faecal indicator bacteria levels have improved which may be attributed to improvements in municipal wastewater treatment.
- The Tarawera Estuary has the highest median *E.coli* concentrations of the river estuaries, although only one result exceeded the ‘red alert’ mode.
- The nitrogen to phosphorus ratio suggests the estuary is nitrogen limited but productivity may also be light limited due to the amount of colour in the estuary.

5.1.5 Kaituna River Estuary

- Dissolved inorganic nitrogen shows an increasing trend. Ammonium is decreasing and this is likely to be strongly influenced by improvements to a meat works discharge to the lower river.
- Dissolved reactive phosphorus is increasing although this not reflected in chlorophyll-a which is showing a decreasing trend.
- Turbidity is decreasing and this may be due to a reduction in cyano-bacterial blooms since 2010.
- Enterococci have increased, however faecal indicator bacteria levels show that on average the estuary is suitable for contact recreation. Recreational guidelines can be expected to be exceeded following rainfall events.

5.2 Eastern and central estuaries

Meaningful trends are also apparent for the eastern and central estuaries, these are summarised in Table 5.2 below.

Table 5.2 Water quality trends eastern and central estuaries.

Sites	Suspended solids	Turbidity*	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Chlorophyll-a	Analysis Period
Ōhiwa at Ruatuna							▼	▲	▲	▲		1995 - 2011
Ōhiwa at Port Ohope	▲											1995 - 2011
Waihi								▲	▲	▲		1990 - 2011
Maketu	▲											1990 - 2011

▲ = meaningful increase; △ = significant increase; ▼ = meaningful decrease; ▽ = significant decrease; na = not analysed. * analysed from 1996.

5.2.1 Ōhiwa Harbour

- There is an increasing trend for suspended solids particularly in the southern harbour - this is most likely due to the effects of several intense storm events since 2004. Fine sediment is likely to be impacting the harbour ecology.
- There are increases in ammonium and indicator bacteria in the eastern estuary but these are not yet at levels exceeding relevant guidelines.

5.2.2 Waihī Estuary

- Faecal contamination is increasing and it seems most likely that this is due to the impacts of agriculture in the lower catchment. Despite this the recreational water quality guidelines are rarely exceeded.
- The recent appearance of the macro-algae *Gracilaria chilensis* could signal increasing eutrophication in the upper estuary.
- TOx-N average concentrations are above the ANZECC (2000) trigger level for ‘slightly disturbed estuarine ecosystems’. There is a strong correlation between dissolved inorganic nitrogen and soluble phosphorus which indicates that freshwater inputs may have the largest influence on the nutrient status and productivity of the estuary.

5.2.3 Maketū Estuary

- Suspended solid concentrations are showing a significant increase. Climatic influences are likely to be the main driver for this trend.
- Indicators of faecal contamination (e.g. *E.coli*) are relatively stable but show high variability. Some improvement is apparent in recent years and this is likely to be due to reduced impact from point sources and reticulation of sewage from the Maketū township.
- The bacterial guidelines for recreational use are rarely exceeded.

- As with Waihī Estuary, the recent appearance of the macro-algae *Gracilaria chilensis* could signal increasing eutrophication in the upper estuary.
- TOx-N and ammonium average concentrations are above the ANZECC (2000) trigger level for ‘slightly disturbed estuarine ecosystems’. The negative correlation of dissolved inorganic nitrogen with salinity indicates the large influence of freshwater inputs on these parameters.

5.3 Tauranga Harbour

A number of meaningful water quality trends are apparent in Tauranga Harbour, these are summarised in Table 5.3 below.

Table 5.3 Water quality trends, Tauranga Harbour.

Sites	Suspended solids	Turbidity*	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Chlorophyll-a	Analysis Period
Southern Harbour												
Maugatapu		▼	▲	▲			▼					1991 - 2013
Waipu Bay							▼					2004 - 2013
Whareroa	▲										▲	1998 - 2013
Pilot Bay					▲	▼						2007 - 2013
Otumoetai	▲					▼			▲	▲		1991 - 2013
Te Puna	▲								▲	▲		1991 - 2013
Ōmokoroa				▲			▼	▲	▲		▼	1991 - 2013
Pahoia												1998 – 2013
Grace St						▼	▼	▼				*1991 - 2013*
Kulim Ave							▼	▼				*1991 - 2013*
Northern Harbour												
Kauri Point				▲								1998 – 2013
Tanners Point											▲	1998 – 2013
Bowentown	▲										▲	1998 – 2013

▲ = meaningful increase; △ = significant increase; ▼ = meaningful decrease; ▽ = significant decrease; na = not analysed. * analysed from 1996. Italic are low tide sites.

5.3.1 Southern Harbour

- There are decreasing trends in turbidity and phosphorus in the upper reaches of Town Basin (Maungatapu), however there is no decreasing trend in suspended solids. TP and DRP are showing decreasing trends at a number of sites including Grace Street and Kulim Avenue.
- Three sites had increasing suspended solid concentrations, Te Puna, Otumoetai and Whareroa. There is some indication that this increase is climatically influenced.

- Overall water clarity is good meeting estuarine water quality guidelines the majority of the time.
- Dissolved inorganic nitrogen has shown increasing trends at Maungatapu, on average the highest concentrations are in the southern harbour. TOx-N also has an increasing trend at Ōmokoroa.
- Freshwater inputs are likely to be influencing dissolved inorganic nitrogen concentrations - this can be seen at the Grace Street site where higher TOx-N concentrations occur at lower conductivities (or salinity).
- There is insufficient data for trend analysis of total nitrogen over the past two decades, however annual observations at Te Puna and Ōmokoroa indicate that an increase in total nitrogen has occurred. One significant trend in total nitrogen was observed over a shorter timeframe at Pilot Bay.
- Pahoia, in the upper reaches of the southern harbour, has the highest median chlorophyll-concentrations. Phytoplankton biomass is higher in the upper harbour due to retention of nutrients but growth can be phosphorus limited.
- Faecal indicator bacteria rarely exceed the guidelines for contact recreation.
- Both low tide sites display decreasing trends in *E.coli*, however Ōmokoroa, Te Puna and Otumoetai have increasing trends in indicator bacteria.

5.3.2 Northern Harbour

- Very few trends have been observed in the northern harbour, indicating that water quality is for the most part stable.
- A meaningful long term trend of increasing TOx-N occurred at Kauri Point.
- Suspended solids (SS) shows an increasing meaningful trend at Bowentown. All three northern harbour sites shows some correlation of SS with chlorophyll-a and TP.
- Both Tanners Point and Bowentown have an increasing meaningful trend for chlorophyll-a. These trends coupled with a relationship with TP may indicate some phosphorus limitation.

5.4 Conclusions

Nitrogen in the form of total oxides of nitrogen (TOx-N) has shown an increasing trend in several estuaries. River estuaries are the most common group with this trend potentially reflecting the increasing agricultural intensity in some catchments. In Tauranga Harbour there is evidence to suggest TOx-N is from terrestrial sources, leading to an increase in total nitrogen at some sites.

Ammonium has shown a decreasing trend in the Kaituna and Tarawera river estuaries and this may be the result of reduced organic nitrogen in the system or, as TOx-N is increasing, greater nitrification of ammonium could be occurring. Changes in the nitrogen balance seem to have had little impact on productivity in the water column, although blooms of macro-algae have been observed particularly in Tauranga Harbour, Maketū and Waihī estuaries. Improvements in ammonium levels can be due to improved effluent discharge quality, but can also occur as increased microbial activity oxidises ammonium to nitrite to nitrate-nitrogen.

Increasing nitrate-nitrogen is often seen in rivers that flow from intensive pastoral agriculture and it is not surprising that similar increases can be seen in some estuaries in the Bay of Plenty. While the levels of nitrate in estuaries often exceeds the ANZECC guidelines there is little evidence to suggest that this is resulting in higher algal biomass (phytoplankton) in the water column. Some areas, such as in the Northern Tauranga Harbour, do show increasing water column productivity however nuisance blooms are largely confined to macro-algae such as sea lettuce. The recent blooms of macro-algae in Waihī and Maketū estuaries have occurred in the absence of any trends in water column nutrient levels and illustrate that the relationships between nutrient dynamics and algal growth are highly complex.

Soluble phosphorus is also showing increasing trends in three of the river estuaries. Continued increases may be a concern in the Kaituna where it appears that the estuary is phosphorus limited, whereas other river estuaries display co-limitation of nitrogen and phosphorus. The decreasing trend in total phosphorus at many of the Tauranga Harbour southern sites is likely to be a result of changes in the combination of suspended inorganic and organic matter. Reduction of point source discharges into the southern harbour, particularly in the early 1990's, are also likely to have had an influence on some trends. Particulate phosphorus correlates well with chlorophyll-a concentrations, suggesting that much of this trend may be influenced by changing productivity in the water column. Productivity increases are apparent at some sites in Tauranga Harbour, most notably in the northern harbour. Overall, most estuaries display little change in water column productivity, with chlorophyll-a concentrations remaining low, indicating estuarine waters are in sound ecological condition.

Other studies have found Bay of Plenty estuaries to be impacted by slight to moderate nutrient enrichment, deposition of mud, and low level heavy metal accumulation (Ellis et al., 2013; Park, 2011 and 2014). Benthic macrofauna surveys show wide variability in the diversity and abundance of dominant taxa as well as changes in sediment parameters. However, with the exception of one site in Ōhiwa Harbour, there is little indication of an overall decline in ecological condition (Park, 2010). These surveys have not targeted all estuarine areas and it is possible that the more sensitive sub-estuaries have lower ecological health.

Improvement in the quality of point source discharges to the Kaituna and Tarawera Rivers has resulted in improving trends for some water quality parameters. The Kaituna shows improving nitrate-nitrogen levels and *E.coli*, while turbidity, suspended solids and water clarity have improved in the Tarawera River estuary.

Increasing trends in suspended solids at Ōhiwa, Maketū and some Tauranga sites is likely, in part, to be due to climatic influences introducing sediment during intensive rainfall events and re-suspension of sediment due to wave and wind action. Recommendations for improving trend detection in suspended solids are given in the next section.

Several estuarine sites are showing increasing trends for faecal indicator bacteria, however the levels of these rarely exceed contact recreation standards. River estuaries have higher concentrations due to the greater fresh water influence and the direct impacts of surface water runoff from rainfall events.

Trend analysis has been used here to show how individual parameters are changing in each estuary. However this can paint a contradictory picture of estuarine health as most estuary sites have both increasing and decreasing trends for different water quality parameters. This is due to a large extent to the complexity of factors that influence estuaries, including point and diffuse discharges, the influence of rainfall events, uptake and deposition of contaminants, and tidal effects. Regardless of this, continued improvement in point source discharges and land management practices, and restoration of wetlands and riparian areas should see estuarine water quality steadily improve overall.

Limit setting under the National Policy Statement for freshwater will help to address such issues together with an integrated management approach that encompasses estuarine environments.

Part 6: Recommendations

There are few New Zealand based water quality guidelines to determine if the estuarine ecological health is being compromised. Comparison of nutrient water quality with current guidelines is not wholly appropriate for the Bay of Plenty situation as adjacent relatively clean open coastal waters will often not meet these standards. Changing ecological and water quality gradients over estuaries also make comparison with guidelines difficult. In the estuarine environment there may also exist a number of eco-regions potentially requiring a number of comparative measures.

Recommendation one: Development of water quality guidelines and/or criteria for Bay of Plenty estuaries related to a predetermined reference state.

Trend information is often a more appropriate diagnostic tool for assessing if there is a departure from historic quality than comparative methods, and is also useful in determining if the tools and mechanisms deployed to maintain, enhance or improve water quality are having an effect.

Assessing the nature and magnitude of temporal trends in environmental monitoring data is not necessarily straightforward. Many environmental datasets do not necessarily follow simple trends or patterns (e.g. linear changes over time) that can be described using simple descriptive parameters (e.g. linear “regression slopes” or “rates of change”). Rather, trends can change in magnitude and/or direction over time in response to the combinations of many influential variables, both natural and anthropogenic (e.g. climatic variation, catchment development, implementation of management interventions such as storm water treatment). This potential complexity needs to be considered when interpreting the trend analysis results.

In addition, the “robustness” of trend monitoring results may be affected by factors associated with the monitoring itself – for example; analytical variability, length of monitoring period, consistency in sampling and analysis methods over time, and monitoring site disturbance.

Waves can have a significant effect on sediment distribution by eroding shores, stripping substrates, and suspending sediment for current dispersal. Eroded material is redistributed offshore or transported into the estuary. As much of sites used in the estuary are shallow and therefore can be more easily influenced by wave and winds action, stirring up sediments, particularly fine sediments, a range of parameters can therefore be influenced at these sites. Consideration of such disturbances may need to be explored as part of the natural range of water quality experienced in the estuarine environment. However, these events complicate interpreting trends when there are already a multitude of complexities. One such example observed on Tauranga harbour is that of an increasing trend in suspended solids at one site, but on closer examination of the data, one observes an increased number of high wind events which have potentially disturbed shallow sediments. This masks the real trend leaving the question of increasing sedimentation uncertain.

Another complexity is the tidal variations experienced in the estuarine environment. The NERMN estuarine programme has historically focused on monitoring mid-high tide. The risk of sampling at this stage of the tidal cycle is that mostly oceanic water is sampled and that monitoring analyses may be detecting changes in oceanic conditions rather than estuarine, or that trend detection ability is reduced. There is also a practical difficulty in monitoring at a similar time of day and at a consistent tidal cycle for a given site, which influences the comparability of data.

While the relevance of open coastal waters on estuarine water quality can be important in assessing estuarine ecological health, there are limited actions that can be undertaken based on impacts from open coastal waters. Emphasis should be on impacts on the estuarine ecological health from terrestrial inputs which have a greater anthropogenic influence. Given this, what sampling and analytical design is required to determine and minimise potential adverse effects on the estuarine environment based on key issues of sedimentation from land run-off, stormwater and microbial contamination? Monitoring programs needs to be flexible enough to help determine whether planning mechanisms are effective in maintaining, enhancing, or improving estuarine water quality. This requires an integrated monitoring approach with greater emphasis on inputs to estuarine systems as well as the ability to detect changes within estuarine systems.

It is frequently difficult to distinguish natural ecosystem variability associated with net primary production from that induced by anthropogenic stress, especially nutrient enrichment, which often is a consequence of variability in physical processes. One such example is prevalent in Tauranga harbour, that of intermittent blooms of sea lettuce. Distinguishing the underlying mechanisms controlling events such as algal blooms can require broad scientific input over and above the scale undertaken at a regional level. Nutrient water column concentrations can be influenced by internal cycling of sediment held nutrients over relatively short timescales (hours) especially during periods of low flow (Pierson *et. al*, 2002). This can make it difficult to make assumptions about ecological condition based on water column concentrations.

Macrobenthic communities are considered good indicators of ecosystem health because of their strong link with sediments, which, at the same time, are linked to the water column (Dauer et al., 2000). Hence, benthos shows the real effects of pollution over the communities, being an integrator of the recent pollution history in the sediment and of different kinds of pollutants, which can act synergistically: as such, they are a good indicator and overcome much of the variability seen in the water column.

In light of these complexities recommendation two makes a range of suggested changes to the current programme.

Recommendation two: Modify the current water quality estuarine programme to better link with fluvial (river and stream) and estuarine ecological monitoring. Changes should include:

- Monitoring of water column using grab samples should occur monthly to improve trend detection.
- Monitoring of river estuaries on outgoing low tides, and ideally monitoring should occur when other sites on the respective river are monitored.
- Removal of the Ōpōtiki Wharf site – there is good correlation between sites indicating that one site in the Ōpōtiki River Estuary will be adequate for the programme.
- Determine whether nutrient, sediment and bacterial loads to the Eastern estuaries are changing and relate to changes in primary productivity. This will require better quantification of loads of these contaminants to the estuaries.
- Tauranga Harbour – retain channel monitoring sites: Pilot Bay; Whareroa; Maungatapu; Ōmokoroa; and north harbour sites. Move Te Puna at Pitua Road to the end of Waipa Road. Add a site in the main channel opposite Motutangaroa Island. Sites should be monitored on the mid-low (outgoing) tide.
- Establish high frequency measures of temperature, salinity, turbidity, dissolved oxygen and chlorophyll-a at a number of sites (upper and lower estuary). The locations need to be chosen so that it is possible to detect impacts of significant rainfall events on the estuary, salinity gradients and seasonal changes.
- Build better synergies with other programmes that may be collecting data in relevant locations. For example the bathing surveillance programme collects data on faecal indicators but could collect salinity, conductivity, turbidity, dissolved oxygen, temperature, and

chlorophyll-a using hand held sensors which would provide a wealth of data over a range of tidal conditions.

- Consider surveys of sediment structure and distribution across estuaries, along with high frequency monitoring to establish exposure times for suspended solids. This will add valuable insight into the potential degrading effects suspended silts and clays can have on estuarine food-webs.

These changes would improve the detection of the impacts of inflows to local water quality and in the long-term improve trend detection relative to terrestrial inputs. High frequency monitoring will give a sensitive response to these inputs and that of oceanic waters over the entire tidal range and will help fill some of the current and future modelling data needs. More intensive monitoring of any density stratification that occurs with large freshwater inflows may be needed to further establish estuarine vulnerability to nutrient enrichment and the effect of this on productivity.

Reduced flow to an estuary can also results in rapid changes to estuarine environments, so some consideration on the stability and quantity of inflow is also required to maintain estuarine health. The Kaituna re-diversion project is an example of estuarine restoration, re-introducing more freshwater to the estuary restoring ecological gradients and reducing oceanic sediment ingress. Changes to the salinity gradient due to reduced inflows can result in multiple ‘knock-on’ effects from growth of invasive macro-flora and algae to ecosystem collapse.

Recommendation three: Investigation into the minimum flows (including groundwater) required to sustain salinity gradients in Waihī, Maketū (underway) and Tauranga Harbour. This potentially would require the development of catchment runoff models to estuaries (accounting for water extraction); and a model of flow and salinity within the estuaries.

Bay of Plenty estuaries cross a number of classification and classification systems, are impacted and react differently to a myriad of catchment characteristics unique to their situation. Regionally and nationally these are difficult to compare and while this report has drawn on some comparison to make sense of data a more holistic reporting structure in future may be more useful.

Recommendation four: Ensure that the setting of water quality limits for freshwater (as part of implementation of the National Policy Statement for Freshwater) takes account of the effects on estuaries. This could be enabled by moving to a more holistic reporting framework which takes a ‘mountains to the sea’ approach, rather than the current separate reporting of state and trends for freshwater and estuarine sites. Such an approach would include a process that account for the ‘mauri’ of the waters.

Part 7: References

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Appendices

Appendix 1 – Water quality statistics

Table A.1 Water quality statistics for Opotiki Wharf.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	106	91.8	92.7	65.8	115.5	7.5	1995 - 2013
Temperature (ºC)	110	14.7	13.8	6.7	24.0	4.1	1995 - 2013
Conductivity (mS/m)	109	494.9	203.0	4.7	5680.0	945.0	1995 - 2013
Suspended solids (g/m^3)	110	58.7	5.0	1.0	1280.0	191.8	1995 - 2013
Turbidity (NTU)	101	64.6	3.4	1.1	1700.0	219.2	1996 – 2013
pH	108	7.3	7.3	6.8	7.9	0.2	1995 - 2013
DRP (g/m^3)	107	0.026	0.027	0.001	0.058	0.011	1995 - 2013
Ammonium-N (g/m^3)	107	0.022	0.017	0.002	0.129	0.017	1995 - 2013
TOx-N (g/m^3)	107	0.076	0.070	0.001	0.312	0.064	1995 - 2013
Total Nitrogen (g/m^3)	55	0.203	0.162	0.063	0.970	0.150	1995 - 2013
Total Phosphorus (g/m^3)	105	0.059	0.036	0.009	0.720	0.097	1995 - 2013
Escherichia coli (cfu/100 ml)	104	296	99	1	3300	608	1995 - 2013
Enterococci (cfu/ 100 ml)	108	144	51	1	1700	276	1995 - 2013
Faecal coliforms (cfu/100 ml)	106	479	160	1	7300	1117	1995 - 2013
Chl-a (mg/m^3)	102	0.36	0.11	0.00	5.10	0.72	1995 - 2013

Table A.2 Water quality statistic for Opotiki at Kukumoa.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	134	93.4	94.2	68.7	111.4	6.5	1990 - 2013
Temperature (ºC)	138	15.4	14.9	7.5	25.0	4.1	1990 – 2013
Conductivity (mS/m)	136	1038	734	8	5270	1168	1990 – 2013
Suspended solids (g/m^3)	138	27.5	6.3	1.4	540.0	68.6	1990 – 2013
Turbidity (NTU)	102	30.2	3.8	1.3	560.0	83.2	1996 – 2013
pH	133	7.5	7.4	6.3	8.2	0.3	1990 – 2013
DRP (g/m^3)	135	0.018	0.017	0.005	0.062	0.008	1990 – 2013
Ammonium-N (g/m^3)	133	0.027	0.022	0.001	0.191	0.023	1990 – 2013
TOx-N (g/m^3)	119	0.065	0.033	0.001	0.283	0.066	1990 – 2013
Total Nitrogen (g/m^3)	64	0.210	0.168	0.023	0.830	0.143	2005 – 2013
Total Phosphorus (g/m^3)	129	0.046	0.029	0.012	0.526	0.060	1990 – 2013
Escherichia coli (cfu/100 ml)	132	227	54	1	7000	759	1990 – 2013
Enterococci (cfu/ 100 ml)	136	136	25	1	5700	568	1990 – 2013
Faecal coliforms (cfu/100 ml)	134	438	140	1	17000	1560	1990 – 2013
Chl-a (mg/m^3)	117	0.51	0.30	0.00	9.10	0.95	1992 - 2013

Table A.3 Water quality statistic for Ruatuna Road.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	133	85.5	83.9	66.3	117.7	8.5	1995 - 2013
Temperature (ºC)	139	17.1	16.2	10.9	25.8	3.6	1995 – 2013
Conductivity (mS/m)	136	5007	5185	794	5480	583	1995 – 2013
Suspended solids (g/m^3)	139	18.9	14.1	1.1	98.0	15.0	1995 – 2013
Turbidity (NTU)	103	6.0	4.6	1.1	33.0	5.3	1996 – 2013
pH	134	8.0	8.0	7.0	8.3	0.1	1995 – 2013
DRP (g/m^3)	136	0.009	0.008	0.001	0.025	0.005	1995 – 2013
Ammonium-N (g/m^3)	137	0.020	0.016	0.001	0.095	0.017	1995 – 2013
TOx-N (g/m^3)	120	0.028	0.008	0.001	0.293	0.042	1995 – 2013
Total Nitrogen (g/m^3)	64	0.186	0.186	0.067	0.407	0.078	1995 – 2013
Total Phosphorus (g/m^3)	132	0.024	0.022	0.006	0.071	0.012	1995 – 2013
Escherichia coli (cfu/100 ml)	133	19	1	1	380	54	1995 – 2013
Enterococci (cfu/ 100 ml)	137	19	2	1	360	49	1995 – 2013
Faecal coliforms (cfu/100 ml)	136	35	4	1	970	116	1995 – 2013
Chl-a (mg/m^3)	118	0.78	0.62	0.05	3.86	0.55	1995 - 2013

Table A.4 Water quality statistic for Port Ohope.

	n	Mean	Median	Maximum	Minimum	SD	Data period
DO%	135	84.4	83.6	64.3	119.2	7.8	1995 - 2013
Temperature (ºC)	140	17.0	16.3	11.5	24.7	3.3	1995 – 2013
Conductivity (mS/m)	135	5075	5220	3060	5510	421	1995 – 2013
Suspended solids (g/m^3)	133	32.1	33.0	6.0	37.1	4.3	1995 – 2013
Turbidity (NTU)	139	19.2	16.0	2.1	75.0	12.7	1996 – 2013
pH	102	6.9	4.9	1.2	62.2	7.6	1995 – 2013
DRP (g/m^3)	135	8.0	8.0	7.5	8.3	0.1	1995 – 2013
Ammonium-N (g/m^3)	137	0.008	0.007	0.001	0.032	0.005	1995 – 2013
TOx-N (g/m^3)	137	0.016	0.010	0.001	0.158	0.020	1995 – 2013
Total Nitrogen (g/m^3)	121	0.026	0.008	0.001	0.393	0.046	1995 – 2013
Total Phosphorus (g/m^3)	66	0.213	0.189	0.022	1.010	0.148	1995 – 2013
Escherichia coli (cfu/100 ml)	133	0.033	0.022	0.006	0.976	0.084	1995 – 2013
Enterococci (cfu/ 100 ml)	135	12	1	1	600	55	1995 – 2013
Faecal coliforms (cfu/100 ml)	139	12	1	1	410	46	1995 – 2013
Chl-a (mg/m^3)	138	18	2	1	600	62	1995 - 2013

Table A.5 Water quality statistic for Whakatāne River Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	134	90.7	91.3	67.3	122.1	8.1	1990 - 2013
Temperature (ºC)	138	16.1	15.6	7.0	24.8	4.1	1990 - 2013
Conductivity (mS/m)	136	1978	1388	8	5740	1776	1990 - 2013
Suspended solids (g/m^3)	138	20.4	8.9	2.8	270.0	37.9	1990 – 2013
Turbidity (NTU)	100	15.5	4.0	0.9	225.0	33.8	1996 – 2013
pH	133	7.6	7.7	6.5	8.3	0.3	1990 – 2013
DRP (g/m^3)	134	0.017	0.017	0.001	0.045	0.009	1990 – 2013
Ammonium-N (g/m^3)	134	0.032	0.026	0.001	0.118	0.024	1990 – 2013
TOx-N (g/m^3)	118	0.110	0.076	0.001	1.020	0.135	1993 – 2013
Total Nitrogen (g/m^3)	66	0.293	0.237	0.022	1.230	0.209	1995 – 2013
Total Phosphorus (g/m^3)	131	0.047	0.032	0.006	0.564	0.064	1990 – 2013
Escherichia coli (cfu/100 ml)	129	206	72	1	4300	508	1990 – 2013
Enterococci (cfu/ 100 ml)	135	119	21	1	5700	518	1990 – 2013
Faecal coliforms (cfu/100 ml)	131	530	170	1	13000	1395	1990 – 2013
Chl-a (mg/m^3)	117	0.66	0.49	0.05	4.30	0.73	1993 - 2013

Table A.6 Water quality statistics for Rangitāiki River Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	106	94.5	94.6	69.4	124.2	8.3	1995 - 2013
Temperature (ºC)	108	14.8	14.4	8.7	24.1	3.6	1995 – 2013
Conductivity (mS/m)	108	261.4	49.2	5.0	3620.0	597.4	1995 – 2013
Suspended solids (g/m^3)	109	11.5	5.4	1.8	135.0	17.9	1995 – 2013
Turbidity (NTU)	103	8.9	3.4	1.2	125.0	17.2	1996 – 2013
pH	109	7.1	7.2	6.5	7.9	0.2	1995 – 2013
DRP (g/m^3)	106	0.044	0.037	0.002	0.223	0.028	1995 – 2013
Ammonium-N (g/m^3)	104	0.024	0.020	0.001	0.124	0.018	1995 – 2013
TOx-N (g/m^3)	104	0.371	0.382	0.001	0.884	0.163	1995 – 2013
Total Nitrogen (g/m^3)	60	0.545	0.557	0.188	0.912	0.138	1995 – 2013
Total Phosphorus (g/m^3)	100	0.069	0.059	0.030	0.262	0.034	1995 – 2013
Escherichia coli (cfu/100 ml)	104	175	90	1	2600	324	1995 – 2013
Enterococci (cfu/ 100 ml)	109	94	50	1	1200	152	1995 – 2013
Faecal coliforms (cfu/100 ml)	108	389	175	8	3500	623	1995 – 2013
Chl-a (mg/m^3)	103	2.51	0.74	0.02	13.60	3.30	1995 - 2013

Table A.7 Water quality statistics for Tarawera River Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	104	72.7	73.7	44.2	94.5	10.4	1995 – 2013
Temperature (ºC)	106	16.2	15.7	10.4	23.1	2.6	1995 – 2013
Cond (mS/m)	104	36.7	36.5	25.4	65.7	4.9	1995 – 2013
SS (g/m^3)	106	11.3	8.8	3.0	46.0	7.6	1995 – 2013
Turbidity (NTU)	100	5.4	4.8	2.0	24.0	2.9	1996 – 2013
pH	106	7.3	7.3	6.8	7.6	0.1	1995 – 2013
DRP (g/m^3)	104	0.075	0.073	0.022	0.141	0.020	1995 – 2013
Ammonium (g/m^3)	102	0.046	0.042	0.001	0.124	0.022	1995 – 2013
TOx-N (g/m^3)	101	0.396	0.403	0.226	0.581	0.079	1995 – 2013
TN (g/m^3)	54	0.674	0.650	0.471	0.975	0.112	1995 – 2013
TP (g/m^3)	98	0.113	0.108	0.082	0.177	0.019	1995 – 2013
E.coli (cfu/100 ml)	100	536	305	4	6700	891	1995 – 2013
Ent (cfu/100 ml)	106	196	97	1	4000	438	1995 – 2013
FC (cfu/100 ml)	106	849	500	20	6700	1042	1995 – 2013
Chl-a (mg/m^3)	100	0.65	0.58	0.005	2.00	0.36	1995 – 2013

Table A.8 Water quality statistics for Waihi Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	132	89.1	86.1	65.4	137.3	11.4	1990 – 2013
Temperature (ºC)	136	17.2	16.7	11.9	25.0	3.1	1990 – 2013
Cond (mS/m)	133	4933	5230	522	5460	872	1990 – 2013
SS (g/m^3)	135	19.5	15.0	1.0	170.0	19.2	1990 – 2013
Turbidity (NTU)	108	4.5	2.8	0.4	29.0	5.4	1996 – 2013
pH	135	8.0	8.0	6.0	8.6	0.3	1990 – 2013
DRP (g/m^3)	134	0.013	0.009	0.001	0.125	0.017	1990 – 2013
Ammonium (g/m^3)	132	0.022	0.013	0.001	0.154	0.024	1990 – 2013
TOx-N (g/m^3)	115	0.050	0.024	0.001	1.170	0.123	1993 – 2013
TN (g/m^3)	61	0.233	0.194	0.042	1.690	0.216	1990 – 2013
TP (g/m^3)	128	0.030	0.021	0.007	0.237	0.029	1990 – 2013
E.coli (cfu/100 ml)	129	31	2	1	1000	117	1990 – 2013
Ent (cfu/100 ml)	135	37	3	1	2800	242	1990 – 2013
FC (cfu/100 ml)	133	35	6	1	1000	113	1990 – 2013
Chl-a (mg/m^3)	115	1.44	1.00	0.05	8.70	1.42	1990 – 2013

Table A.9 Water quality statistics for Maketu Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	131	86.6	84.7	43.0	138.3	12.5	1990 – 2013
Temperature (ºC)	136	17.4	16.6	11.7	24.5	3.3	1990 – 2013
Cond (mS/m)	133	4903	5070	2060	5450	577	1990 – 2013
SS (g/m^3)	135	20.5	16.0	3.7	80.0	14.2	1990 – 2013
Turbidity (NTU)	108	5.4	3.9	0.6	38.0	5.3	1996 – 2013
pH	135	8.0	8.0	6.9	8.3	0.2	1990 – 2013
DRP (g/m^3)	134	0.013	0.011	0.001	0.087	0.011	1990 – 2013
Ammonium (g/m^3)	132	0.031	0.020	0.001	0.331	0.041	1990 – 2013
TOx-N (g/m^3)	114	0.057	0.033	0.001	0.659	0.084	1993 – 2013
TN (g/m^3)	62	0.268	0.249	0.047	0.908	0.136	1993 – 2013
TP (g/m^3)	128	0.033	0.029	0.010	0.140	0.017	1990 – 2013
E.coli (cfu/100 ml)	128	33	2	1	2000	190	1990 – 2013
Ent (cfu/100 ml)	134	30	5	1	2000	178	1990 – 2013
FC (cfu/100 ml)	135	41	8	1	2000	189	1990 – 2013
Chl-a (mg/m^3)	117	2.01	1.60	0.05	16.90	1.87	1992 – 2013

Table A.10 Water quality statistics for Kaituna Estuary.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	98	91.0	90.7	57.8	123.9	10.5	1990 – 2013
Temperature (ºC)	101	16.1	15.9	10.7	23.5	3.3	1990 – 2013
Cond (mS/m)	101	1198	776	22	5050	1209	1990 – 2013
SS (g/m^3)	102	8.1	7.0	3.0	31.0	4.5	1990 – 2013
Turbidity (NTU)	98	3.7	3.1	0.5	14.0	2.3	1996 – 2013
pH	99	7.4	7.4	6.6	8.2	0.4	1990 – 2013
DRP (g/m^3)	98	0.024	0.021	0.001	0.426	0.042	1990 – 2013
Ammonium (g/m^3)	97	0.084	0.066	0.001	1.420	0.146	1990 – 2013
TOx-N (g/m^3)	99	0.444	0.461	0.024	0.762	0.146	1993 – 2013
TN (g/m^3)	45	0.765	0.743	0.362	1.250	0.161	199 – 2013
TP (g/m^3)	94	0.050	0.041	0.017	0.855	0.085	1990 – 2013
E.coli (cfu/100 ml)	98	281	68	1	13000	1316	1990 – 2013
Ent (cfu/100 ml)	100	126	39	1	3600	425	1990 – 2013
FC (cfu/100 ml)	101	470	140	4	13000	1350	1990 – 2013
Chl-a (mg/m^3)	98	3.16	2.05	0.40	17.00	3.22	1992 – 2013

Table A.11 Water quality statistics for Maungatapu at bridge.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	119	83.6	82.1	57.7	125.6	11.6	1991 – 2013
Temperature (ºC)	126	16.8	16.7	9.0	24.6	3.7	1991 – 2013
Conductivity (mS/m)	126	4586	4705	2250	5510	578	1991 – 2013
Suspended solids (g/m^3)	127	19.9	15.0	3.4	205.0	19.8	1991 – 2013
Turbidity (NTU)	101	4.4	3.5	0.8	68.0	6.8	1996 – 2013
pH	127	8.0	8.0	7.2	8.3	0.2	1991 – 2013
DRP (g/m^3)	123	0.008	0.007	0.001	0.050	0.006	1991 – 2013
Ammonium-N (g/m^3)	123	0.036	0.028	0.001	0.174	0.028	1991 – 2013
TOx-N (g/m^3)	113	0.079	0.037	0.001	1.450	0.155	1993 – 2013
Total Nitrogen (g/m^3)	58	0.306	0.284	0.105	0.961	0.151	2005 – 2013
Total Phosphorus (g/m^3)	120	0.029	0.024	0.004	0.310	0.031	1991 – 2013
Escherichia coli (cfu/100 ml)	113	16	4	1	390	42	1991 – 2013
Enterococci (cfu/100 ml)	126	19	5	1	500	55	1991 – 2013
Faecal coliforms (cfu/ 100 ml)	120	25	10	1	510	54	1991 – 2013
Chl-a (mg/m^3)	86	1.55	1.00	0.10	13.00	1.65	1998 - 2013

Table A.12 Water quality statistics for Whareroa Point Marina.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	88	83.3	80.5	58.5	113.8	9.8	1998 – 2013
Temperature (ºC)	91	16.7	16.0	11.7	23.5	3.0	1998 – 2013
Conductivity (mS/m)	91	5015	5060	3630	5590	299	1998 – 2013
Suspended solids (g/m^3)	91	14.7	12.0	2.6	48.0	10.2	1998 – 2013
Turbidity (NTU)	90	2.1	1.9	0.7	6.9	0.9	1998 – 2013
pH	91	8.0	8.0	5.7	8.3	0.3	1998 – 2013
DRP (g/m^3)	90	0.008	0.007	0.002	0.030	0.005	1998 – 2013
Ammonium-N (g/m^3)	89	0.025	0.018	0.004	0.157	0.024	1998 – 2013
TOx-N (g/m^3)	91	0.036	0.028	0.001	0.153	0.036	1998 – 2013
Total Nitrogen (g/m^3)	47	0.254	0.241	0.098	0.873	0.125	1998 – 2013
Total Phosphorus (g/m^3)	84	0.020	0.016	0.002	0.270	0.028	2005 – 2013
Escherichia coli (cfu/ 100 ml)	90	10	2	1	220	28	1998 – 2013
Enterococci (cfu/100 ml)	90	8	2	1	130	18	1998 – 2013
Faecal coliforms (cfu/100 ml)	90	19	8	1	220	36	1998 – 2013
Chl-a (mg/m^3)	87	0.95	0.80	0.05	3.50	0.61	1998 – 2013

Table A.13 Water quality statistics for Waipu Bay.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	37	49	87.1	84.2	67.2	108.8	2004 – 2013
Temperature (ºC)	39	51	16.7	16.0	11.5	23.3	2004 – 2013
Conductivity (mS/m)	39	51	5082	5090	4180	5520	2004 – 2013
Suspended solids (g/m^3)	39	51	23.5	19.0	6.0	84.0	2004 – 2013
Turbidity (NTU)	39	51	3.4	2.4	0.6	14.0	2004 – 2013
pH	39	51	8.0	8.0	7.6	8.2	2004 – 2013
DRP (g/m^3)	37	49	0.010	0.007	0.001	0.106	2004 – 2013
Ammonium-N (g/m^3)	36	48	0.025	0.022	0.001	0.112	2004 – 2013
TOx-N (g/m^3)	37	49	0.037	0.029	0.001	0.112	2004 – 2013
Total Nitrogen (g/m^3)	32	44	0.251	0.250	0.105	0.520	2005 – 2013
Total Phosphorus (g/m^3)	33	45	0.022	0.018	0.008	0.083	2004 – 2013
Escherichia coli (cfu/ 100 ml)	38	50	10	3	1	110	2004 – 2013
Enterococci (cfu/100 ml)	38	50	8	2	1	59	2004 – 2013
Faecal coliforms (cfu/ 100 ml)	38	49	24	9	1	200	2004 – 2013
Chl-a (mg/m^3)	39	50	1.02	0.80	0.40	2.60	2004 – 2013

Table A.14 Water quality statistics for Grace Street.

	n	Mean	Median	Minimum	Maximum	SD	Data period
Temperature (ºC)	131	19.7	19.2	9.0	30.3	4.7608	1991 – 2013
Conductivity (mS/m)	134	4158	4260	1971	5220	651	1991 – 2013
Suspended solids (g/m^3)	133	40.2	27.0	4.4	355.0	44.1	1991 – 2013
Turbidity (NTU)	102	13.2	7.0	1.1	111.0	16.8	1996 – 2013
pH	131	8.2	8.2	7.4	9.0	0.2	1991 – 2013
DRP (g/m^3)	135	0.008	0.008	0.000	0.052	0.0069	1991 – 2013
Ammonium-N (g/m^3)	134	0.035	0.029	0.001	0.221	0.0278	1991 – 2013
TOx-N (g/m^3)	132	0.102	0.056	0.001	0.746	0.1218	1991 – 2013
Total Nitrogen (g/m^3)	67	0.408	0.361	0.171	1.010	0.1800	2005 – 2013
Total Phosphorus (g/m^3)	132	0.046	0.036	0.009	0.243	0.0331	1991 – 2013
Escherichia coli (cfu/100 ml)	50	29	1	1	330	77	2005 – 2013
Enterococci (cfu/100 ml)	50	22	3	1	180	45	2005 – 2013
Faecal coliforms (cfu/ 100 ml)	50	47	4	1	530	111	2005 – 2013
Chl-a (mg/m^3)	26	2.6	1.7	0.3	9.4	2.5	2005 – 2013

Table A.15 Water quality statistics for Otumoetai Bay.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	120	86.5	83.3	59.0	135.6	14.6	1991 – 2013
Temperature (ºC)	129	16.4	15.9	9.0	26.7	3.6	1991 – 2013
Conductivity (mS/m)	129	4686	4800	1838	5360	530	1991 – 2013
Suspended solids (g/m^3)	130	16.6	11.0	0.6	78.0	15.6	1991 – 2013
Turbidity (NTU)	103	3.5	1.9	0.5	25.0	4.8	1991 – 2013
pH	130	8.0	8.0	5.5	8.4	0.3	1991 – 2013
DRP (g/m^3)	129	0.007	0.006	0.001	0.026	0.004	1991 – 2013
Ammonium-N (g/m^3)	128	0.025	0.021	0.001	0.143	0.022	1991 – 2013
TOx-N (g/m^3)	117	0.041	0.020	0.001	0.299	0.051	1991 – 2013
Total Nitrogen (g/m^3)	68	0.263	0.252	0.087	0.550	0.113	2006 – 2013
Total Phosphorus (g/m^3)	124	0.022	0.018	0.005	0.072	0.013	1991 – 2013
Escherichia coli (cfu/ 100 ml)	119	11	2	1	273	28	1991 – 2013
Enterococci (cfu/100 ml)	130	23	3	1	1000	95	1991 – 2013
Faecal coliforms (cfu/ 100 ml)	124	28	7	1	1000	95	1991 – 2013
Chl-a (mg/m^3)	94	1.31	0.73	0.05	10.30	1.62	1998 - 2013

Table A.16 Water quality statistic for Kulim Street, Otumoetai.

	n	Mean	Median	Minimum	Maximum	SD	Data period
Temperature (ºC)	132	20.0	19.9	10.8	31.8	4.2	1991 – 2013
Conductivity (mS/m)	133	4601	4770	980	5640	701	1991 – 2013
Suspended solids (g/m^3)	132	33.6	15.9	3.6	530.0	62.2	1991 – 2013
Turbidity (NTU)	103	10.6	3.0	1.0	250.0	27.9	1996 – 2013
pH	130	8.4	8.4	4.8	9.3	0.4	1991 – 2013
DRP (g/m^3)	133	0.008	0.007	0.001	0.044	0.005	1991 – 2013
Ammonium-N (g/m^3)	133	0.024	0.017	0.001	0.218	0.024	1991 – 2013
TOx-N (g/m^3)	132	0.067	0.017	0.001	1.456	0.187	1991 – 2013
Total Nitrogen (g/m^3)	67	0.388	0.274	0.029	3.260	0.455	2005 – 2013
Total Phosphorus (g/m^3)	130	0.040	0.024	0.010	0.347	0.050	1991 – 2013
Escherichia coli (cfu/ 100 ml)	49	50	1	1	1100	175	2005 – 2013
Enterococci (cfu/100 ml)	48	24	1	1	540	84	2005 – 2013
Faecal coliforms (cfu/ 100 ml)	48	39	2	1	470	108	2005 – 2013

Table A.17 Water quality statistic for Pilot Bay.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	23	97.3	97.2	81.7	106.1	5.0	2007 – 2013
Temperature (ºC)	39	16.7	16.3	12.7	22.2	2.6	2007 – 2013
Conductivity (mS/m)	40	5155	5200	4160	5690	301	2007 – 2013
Suspended solids (g/m^3)	40	14.4	14.0	3.6	30.0	7.6	2007 – 2013
Turbidity (NTU)	40	1.8	1.7	0.6	4.6	1.0	2007 – 2013
pH	40	8.0	8.0	7.7	8.2	0.1	2007 – 2013
DRP (g/m^3)	38	0.007	0.007	0.001	0.020	0.005	2007 – 2013
Ammonium-N (g/m^3)	37	0.027	0.014	0.001	0.270	0.046	2007 – 2013
TOx-N (g/m^3)	37	0.037	0.023	0.002	0.126	0.034	2007 – 2013
Total Nitrogen (g/m^3)	35	0.212	0.198	0.101	0.406	0.075	2007 – 2013
Total Phosphorus (g/m^3)	38	0.015	0.015	0.010	0.036	0.005	2007 – 2013
Escherichia coli (cfu/ 100 ml)	39	9	1	1	220	36	2007 – 2013
Enterococci (cfu/100 ml)	39	9	1	1	80	19	2007 – 2013
Faecal coliforms (cfu/ 100 ml)	38	19	2	1	280	53	2007 – 2013
Chl-a (mg/m^3)	39	1.01	0.80	0.20	3.60	0.64	2007 – 2013

Table A.18 Water quality statistic for Te Puna.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	123	85.5	82.4	62.2	128.6	12.7	1991 – 2013
Temperature (ºC)	130	16.7	15.9	7.6	26.7	3.8	1991 – 2013
Conductivity (mS/m)	131	4721	4920	679	5300	627	1991 – 2013
Suspended solids (g/m^3)	132	18.6	13.0	1.4	126.0	20.6	1991 – 2013
Turbidity (NTU)	106	3.9	1.9	0.6	33.0	5.6	1996 – 2013
pH	133	8.0	8.0	6.9	8.4	0.2	1991 – 2013
DRP (g/m^3)	132	0.006	0.005	0.001	0.019	0.003	1991 – 2013
Ammonium-N (g/m^3)	128	0.021	0.017	0.001	0.094	0.016	1991 – 2013
TOx-N (g/m^3)	117	0.040	0.019	0.001	0.334	0.055	1991 – 2013
Total Nitrogen (g/m^3)	67	0.263	0.248	0.074	0.705	0.116	2006 – 2013
Total Phosphorus (g/m^3)	129	0.021	0.018	0.005	0.081	0.013	1991 – 2013
Escherichia coli (cfu/ 100 ml)	121	30	2	1	2200	202	1991 – 2013
Enterococci (cfu/100 ml)	132	11	1	1	300	34	1991 – 2013
Faecal coliforms (cfu/ 100 ml)	126	53	4	1	4300	384	1991 – 2013
Chl-a (mg/m^3)	90	1.78	1.10	0.10	13.20	2.22	1998 - 2013

Table A.19 Water quality statistic for Omokoroa

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	122	85.9	83.0	45.4	123.0	11.9	1991 – 2013
Temperature (ºC)	129	17.1	16.6	10.3	25.3	3.7	1991 – 2013
Conductivity (mS/m)	131	4843	4930	3530	5500	327	1991 – 2013
Suspended solids (g/m^3)	131	19.1	15.0	3.3	123.0	14.1	1991 – 2013
Turbidity (NTU)	105	3.8	3.2	0.9	22.0	2.7	1996 – 2013
pH	132	8.0	8.1	7.5	8.5	0.1	1991 – 2013
DRP (g/m^3)	131	0.005	0.004	0.001	0.014	0.003	1991 – 2013
Ammonium-N (g/m^3)	129	0.020	0.014	0.001	0.120	0.019	1991 – 2013
TOx-N (g/m^3)	119	0.027	0.014	0.001	0.171	0.034	1991 – 2013
Total Nitrogen (g/m^3)	67	0.241	0.241	0.096	0.470	0.080	2006 – 2013
Total Phosphorus (g/m^3)	125	0.022	0.018	0.005	0.121	0.013	1991 – 2013
Escherichia coli (cfu/ 100 ml)	119	6	1	1	90	15	1991 – 2013
Enterococci (cfu/100 ml)	130	7	1	1	160	20	1991 – 2013
Faecal coliforms (cfu/ 100 ml)	124	12	2	1	180	26	1991 – 2013
Chl-a (mg/m^3)	119	1.77	1.40	0.05	7.40	1.32	1998 - 2013

Table A.20 Water quality statistic for Pahoia.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	88	89.6	86.7	62.9	121.1	12.7	1998 – 2013
Temperature (ºC)	91	17.2	16.9	9.6	26.2	4.1	1998 – 2013
Conductivity (mS/m)	91	4500	4630	1776	5190	572	1998 – 2013
Suspended solids (g/m^3)	91	29.9	23.0	5.8	264.0	33.1	1998 – 2013
Turbidity (NTU)	90	6.7	4.7	0.8	43.0	5.9	1998 – 2013
pH	91	8.0	8.0	7.5	8.3	0.2	1998 – 2013
DRP (g/m^3)	90	0.003	0.003	0.001	0.018	0.003	1998 – 2013
Ammonium-N (g/m^3)	89	0.022	0.013	0.001	0.091	0.022	1998 – 2013
TOx-N (g/m^3)	90	0.031	0.009	0.001	0.374	0.058	1998 – 2013
Total Nitrogen (g/m^3)	46	0.294	0.288	0.105	0.580	0.099	2004 – 2013
Total Phosphorus (g/m^3)	85	0.021	0.017	0.006	0.059	0.011	1998 – 2013
Escherichia coli (cfu/ 100 ml)	89	15	4	1	170	29	1998 – 2013
Enterococci (cfu/100 ml)	88	14	5	1	110	23	1998 – 2013
Faecal coliforms (cfu/ 100 ml)	87	26	9	1	240	43	1998 – 2013
Chl-a (mg/m^3)	87	1.77	1.40	0.05	12.80	1.70	1998 – 2013

Table A.21 Water quality statistic for Kauri Point.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	85	83.9	81.0	64.5	115.9	10.1	1998 – 2013
Temperature (ºC)	89	16.9	16.3	10.7	24.9	3.3	1998 – 2013
Conductivity (mS/m)	88	4991	5085	3610	5480	339	1998 – 2013
Suspended solids (g/m^3)	89	19.7	18.0	2.9	53.0	11.4	1998 – 2013
Turbidity (NTU)	88	3.2	2.9	0.6	9.5	1.7	1998 – 2013
pH	89	8.0	8.1	7.5	8.4	0.1	1998 – 2013
DRP (g/m^3)	88	0.004	0.004	0.001	0.014	0.003	1998 – 2013
Ammonium-N (g/m^3)	87	0.017	0.012	0.001	0.090	0.016	1998 – 2013
TOx-N (g/m^3)	85	0.020	0.009	0.001	0.177	0.031	1998 – 2013
Total Nitrogen (g/m^3)	43	0.239	0.234	0.105	0.540	0.082	2006 – 2013
Total Phosphorus (g/m^3)	81	0.021	0.015	0.004	0.350	0.038	1998 – 2013
Escherichia coli (cfu/ 100 ml)	87	3	1	1	61	8	1998 – 2013
Enterococci (cfu/100 ml)	88	10	1	1	430	48	1998 – 2013
Faecal coliforms (cfu/ 100 ml)	86	7	2	1	87	14	1998 – 2013
Chl-a (mg/m^3)	84	1.38	1.20	0.30	4.00	0.83	1998 - 2013

Table A.22 Water quality statistics for Tanners Point.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	89	84.3	83.3	62	109.7	12.6	1998 – 2013
Temperature (ºC)	92	17.9	16.3	12.0	99.7	9.2	1998 – 2013
Conductivity (mS/m)	91	5090	5200	15	5660	601	1998 – 2013
Suspended solids (g/m^3)	92	16.4	13.5	2.1	47.0	10.7	1998 – 2013
Turbidity (NTU)	91	2.6	1.9	0.6	53.0	5.4	1998 – 2013
pH	92	8.0	8.1	2.1	8.4	0.6	1998 – 2013
DRP (g/m^3)	90	0.093	0.005	0.001	7.900	0.832	1998 – 2013
Ammonium-N (g/m^3)	89	0.021	0.014	0.001	0.130	0.020	1998 – 2013
TOx-N (g/m^3)	90	0.025	0.009	0.001	0.257	0.042	1998 – 2013
Total Nitrogen (g/m^3)	49	0.203	0.219	0.045	0.420	0.067	2006 – 2013
Total Phosphorus (g/m^3)	81	0.018	0.014	0.005	0.259	0.028	1998 – 2013
Escherichia coli (cfu/ 100 ml)	90	3	1	0	38	7	1998 – 2013
Enterococci (cfu/100 ml)	90	6	1	1	97	15	1998 – 2013
Faecal coliforms (cfu/ 100 ml)	90	7	2	1	49	11	1998 – 2013
Chl-a (mg/m^3)	90	0.87	0.70	0.05	3.10	0.53	1998 - 2013

Table A.23 Water quality statistics for Bowentown.

	n	Mean	Median	Minimum	Maximum	SD	Data period
DO%	88	86.8	84.5	66.7	116.0	10.2	1998 – 2013
Temperature (ºC)	90	17.2	16.8	12.0	25.7	3.2	1998 – 2013
Conductivity (mS/m)	89	5135	5180	3910	5640	263	1998 – 2013
Suspended solids (g/m^3)	90	14.5	12.0	0.4	50.0	10.4	1998 – 2013
Turbidity (NTU)	89	1.8	1.5	0.4	7.3	1.2	1998 – 2013
pH	90	8.1	8.1	7.4	8.3	0.1	1998 – 2013
DRP (g/m^3)	89	0.006	0.005	0.001	0.027	0.005	1998 – 2013
Ammonium-N (g/m^3)	88	0.021	0.016	0.001	0.150	0.020	1998 – 2013
TOx-N (g/m^3)	88	0.020	0.008	0.001	0.167	0.030	1998 – 2013
Total Nitrogen (g/m^3)	45	0.231	0.206	0.105	0.620	0.097	2006 – 2013
Total Phosphorus (g/m^3)	82	0.015	0.014	0.004	0.086	0.009	1998 – 2013
Escherichia coli (cfu/ 100 ml)	88	8	1	1	280	32	1998 – 2013
Enterococci (cfu/100 ml)	88	15	2	1	400	50	1998 – 2013
Faecal coliforms (cfu/ 100 ml)	88	14	3	1	261	33	1998 – 2013
Chl-a (mg/m^3)	87	0.77	0.60	0.05	3.40	0.58	1998 - 2013

Appendix 2 – Coastal Water Quality Classification

Coastal Water Quality Classification – Regional Coastal Environmental Plan (S13.2)

S13.2.1 No discharge shall cause:

- the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials,
- any conspicuous change in the colour or visual clarity,
- any emission of objectionable odour, and
- any significant adverse effects on aquatic life;

in coastal waters, foreshore and seabed within the coastal marine area.

S13.2.2 Within all harbours and estuaries, and into the open coast out to a distance of 400 m from the line of mean high water springs:

- the visual clarity of the water shall not be so low as to be unsuitable for bathing,
- the water shall not be rendered unsuitable for bathing by the presence of contaminants,
- there shall be no undesirable biological growths as a result of any discharge of a contaminant into the water,
- the natural temperature of the water shall not be changed by more than 3 degrees C,
- the concentration of dissolved oxygen shall exceed 80% of saturation concentration, and
- aquatic organisms shall not be rendered unsuitable for human consumption by the presence of contaminants.

Contact Recreation Water Quality Classification – Schedule 10 of the Proposed Regional Water and Land Plan

Any discharge of contaminants or water to water in a river or stream classified, as Contact Recreation in the Water Quality Classification Map shall not alter the quality of the water beyond the following standards after reasonable mixing of the discharge with the receiving water:

(a) The discharge shall not cause the visual clarity of the water to fall below 1.6 m of a horizontal sighting distances of a 200 mm black disc (from Water Quality Guidelines Number 2, Ministry for the Environment, June 1994).

(b) The discharge shall not cause the E. coli level to exceed 126/100 ml as measured by a single sample.

(c) The water shall not be rendered unsuitable for bathing by the presence of contaminants as a result of the discharge at levels exceeding those specified in the Recreational Water Quality Guidelines, Ministry of Health/Ministry for the Environment, November 1999.

(d) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.

(e) The discharge of contaminants (either by itself or in combination with the same, similar, or other contaminants) or water to water shall not cause:

    (i) The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials.

    (ii) Any conspicuous change in the colour or visual clarity, subject to (a).

(iii) Any emission of objectionable odour (refer to the Operative Bay of Plenty Regional Air Plan).

(iv) The rendering of fresh water unsuitable for consumption by farm animals (refer to ANZECC Guidelines for Fresh and Marine Water Quality, 2000).

(v) Any significant adverse effects on aquatic life (refer to ANZECC Guidelines for Fresh and Marine Water Quality, 2000).

Explanation/intent of Classification

To ensure that the contact recreation values of rivers and streams classified as Contact Recreation are protected from the adverse effects of discharges. The standards are based on the CR (contact recreation) water quality class of the Third Schedule and section 70 of the Resource Management Act 1991, and relevant national standards. The E. coli limit is set to allow for bathing suitability.