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TE RAUHITANGA TAIAO

WATER QUALITY SURVEYS OF MAHURANGI HARBOUR, UPPER WAITEMATA HARBOUR & TAMAKI ESTUARY 1992 - 2001

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1992 – 2001

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September 2002

Water Quality Surveys of Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary

1992 – 2001

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Prepared for

Auckland Regional Council

NIWA Client Report: ARC02277/2
September 2002

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CONTENTS

Executive Summary

The Auckland Regional Council and its antecedent organisations have been monitoring water quality as part of the Long-Term Baseline (LTB) monitoring programme since the mid-1980s. In this report monitoring data from special investigations of sites in Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary are treated in the same way as the other LTB sites. Time series graphs are presented for the period 1992-2001 and statistical analyses have been carried out summarising both the long-term records for the each site, and for the year January-December 2001. Box plots and ANOVA have enabled sites to be compared within each of the three water bodies.

The data shows that Mahurangi Harbour and Upper Waitemata Harbour have generally good water quality, with improving trends for water clarity. Tamaki freshwater stream sites have the poorest water quality in terms of DO associated with high rates of primary production, and elevated levels of faecal bacteria. Several sites of Tamaki Estuary and, to a lesser extent, Mahurangi Harbour have high faecal bacteria concentrations that probably derive from human activities.

Tamaki Estuary has the worst water quality of the three water bodies, as might be expected in terms of its catchment population, but is showing improving trends in SS, DO and NH_4-N concentrations.

ANOVA has been used to compare sites and rank them in terms of overall water quality. Long-term median concentrations for SS, turbidity, DO (% sat), NH_4-N, NO_2-N, NO_3-N, DRP, TP, total coliform and faecal coliform were ranked from best (lowest value) to worst (highest) and summed to give an overall ranking for each site within a given water body. The results are as follows, where sites are ranked from best water quality (lowest rank sum) to worst (highest rank sum) water quality.

Mahurangi Harbour: Mahurangi heads < Dawson's Creek (surface and 1 m) << Town Bridge < Supply Jetty < Town Basin (surface and 1 m)

Upper Waitemata Harbour: Hobsonville Jetty < Waimarie Road < Brigham's/Rangitopuni confluence ≈ Paremoremo Ski Club < Lucas Creek < Rarawaru Creek < Rangitopuni Creek < Brigham's Creek

Tamaki Estuary: No. 7 Buoy (surface and 5m) < Panmure Basin < Otara Creek < Pakuranga Creek – Botany < Otaki Creek < Pakuranga Creek – Guys < Omaru Creek < Pakuranga Creek – Greenmount

This analysis shows the marine sites furthest from land-based sources of pollution (viz. Mahurangi Heads, Hobsonville Jetty and No. 7 Buoy) to have the best overall water quality.

1. INTRODUCTION

The Auckland Regional Council (ARC) and its predecessor agency, the Auckland Regional Authority's Regional Water Board (ARWB), have regularly monitored freshwater streams since 1986, lakes since 1992 and saline (coastal and harbour) sites since 1987. This monitoring is referred to as the Long-Term Baseline Water Quality (LTB-WQ) network. The data is reviewed annually.

Sampling of sites in Upper Waitemata Harbour (UWH) and Tamaki Estuary commenced during the mid-1980s and was followed by sampling of sites within Mahurangi Harbour. The monitoring of sites within the three water bodies, referred to as the "special survey sites", was undertaken because of specific local issues within each of these semi-enclosed water bodies. Monitoring sites were chosen to represent particular local components of each survey area, in contrast with the other LTB sites, which are chosen to be regionally representative. In the Mahurangi catchment there is a small rural township at the head of the estuary, and rural and lifestyle land use elsewhere in the catchment. There is proposed urban development around the township and alongside the harbour near the mouth. Within the harbour there is commercial oyster farming and high recreation use near the mouth. UWH has five estuarine arms (Rangitopuni is the largest freshwater input); there are some urban developments, two military airfields, a maximum-security prison and light commercial activity. Tamaki Estuary is one of the most highly impacted water bodies in the Auckland region and water quality has been monitored since 1985 (ARC 1999).

The purpose of the special surveys is to answer the key questions:

1. What is the current water quality of these water bodies, and are they getting better or worse?

2. How does land use affect water quality?

3. How does water quality affect regional policy and programmes (and *vice versa*), and public perception of water?

Subsidiary to these aims are:

1. Identification of the present and potential impacts of catchment development activities;

2. Collection of baseline data for calibration of short-term surveys of similar areas;

3. Evaluation of improvement in water quality in response to pollution abatement activities;

4. Assessment of the effectiveness of land use planning policies intended to protect water quality;

5. Ensuring that existing environmental controls are adequate to avoid unacceptable adverse environmental impacts.

This report reviews all data collected at monthly intervals from the special survey sites from 1992 to December 2001. Improved quality control and assurance measures were introduced in a regular and systematic manner in 1992 and for that reason less reliance can be placed on the pre-1992 data.

2. SAMPLING SITES AND SURVEY DETAILS

All monitoring of the special survey sites is done either from land access bridges or from boats. The location of sites in Mahurangi Harbour, Tamaki Estuary and UWH are shown in Figs. 2.1-2.3. Data from an additional Tamaki Estuary site that is not shown in Fig. 2.2, Otara Lake at weir, is also included. This site was monitored from 16/5/95 – 20/2/01 to provide information relevant to the Otara Lake Accord between Manukau City Council, Contact Energy and ARC concerning possible upgrading of the amenity value of the area for residents and visitors. The data is a useful adjunct to that from other sites in the area.

A list of sites and their locations (map references), as well as periods that each has been monitored, is given in Table 2.1 in the order in which they are sampled in each area.

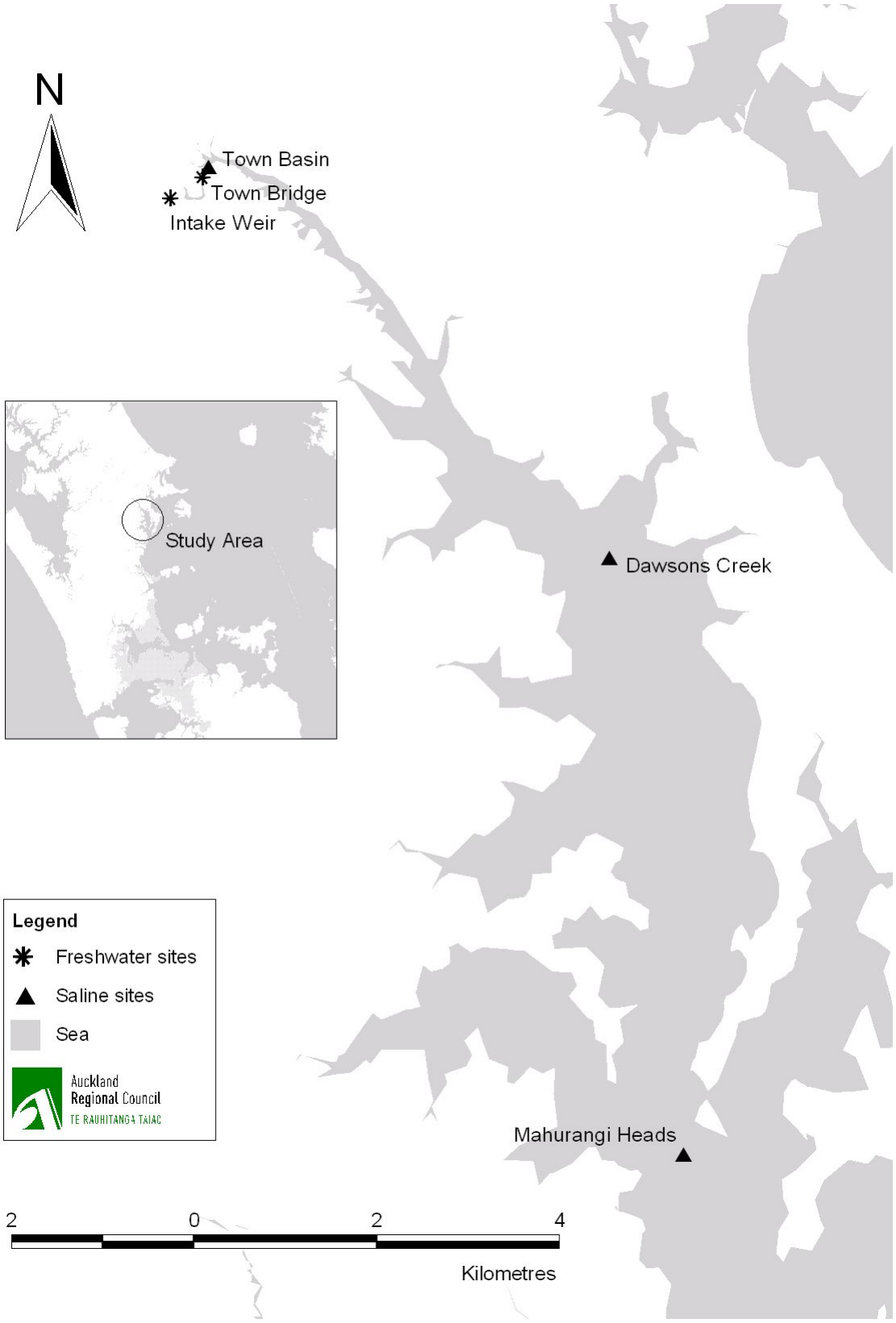

Fig. 2.1 Location of Mahurangi Harbour special survey sites.

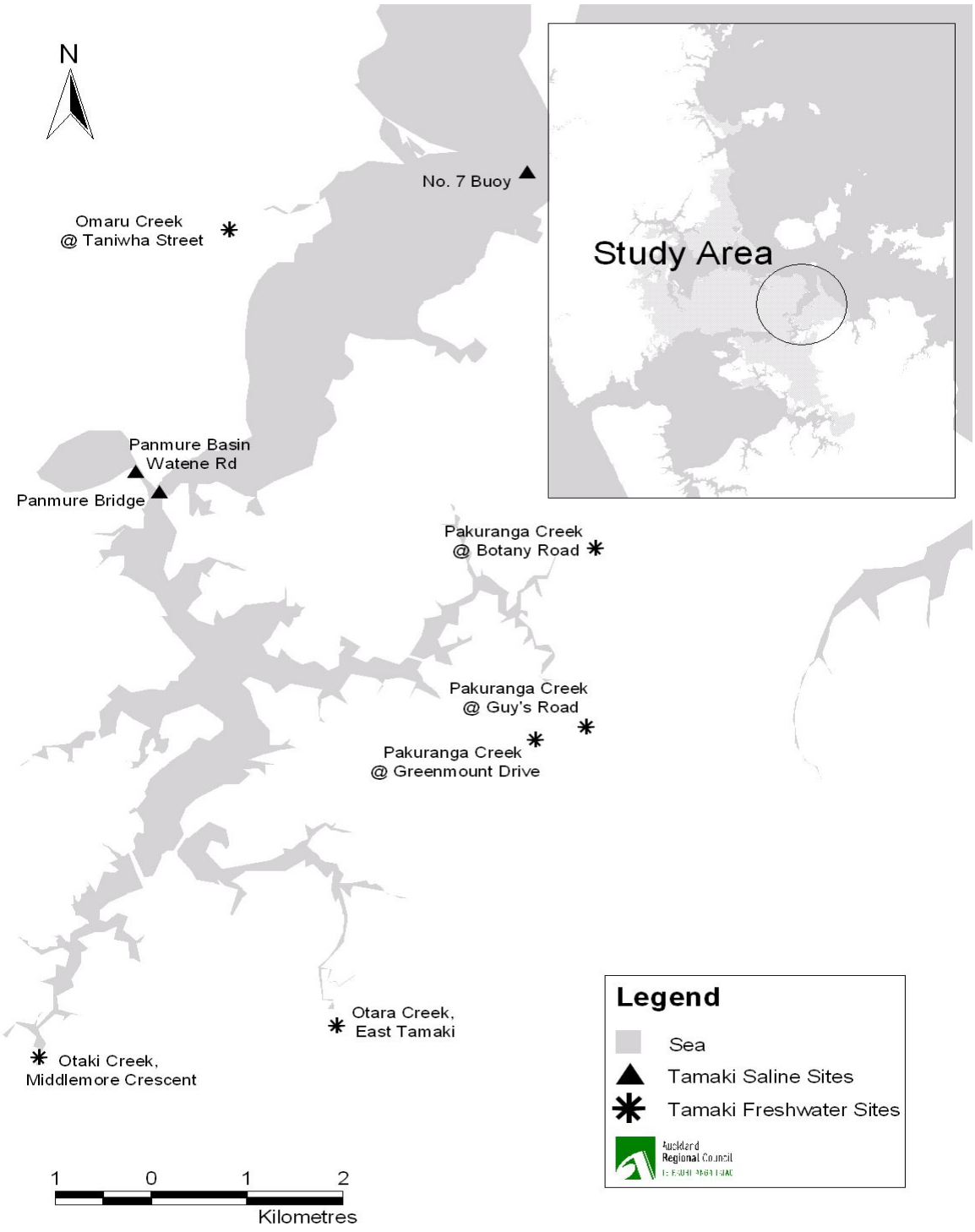

Fig. 2.2 Location of Tamaki Estuary special survey sites.

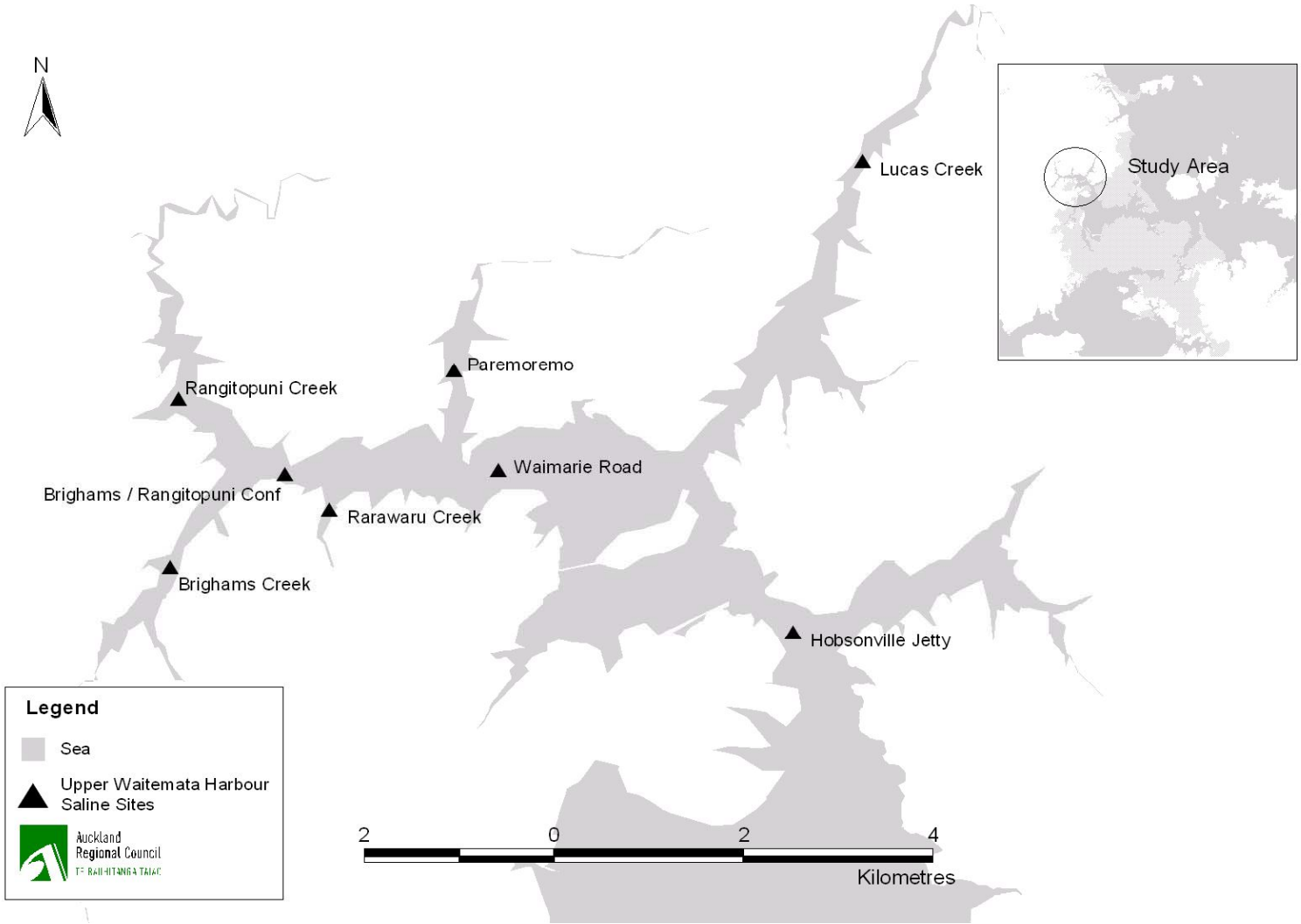

Fig. 2.3 Location of Upper Waitemata Harbour special survey sites

Table 2.1 Special survey monitoring sites (codes), map references and monitoring periods.

Site (code)	Depths (m)	Map reference NZMS 260	Monitoring period
Mahurangi streams			
Supply Intake Jetty (M01)	0	R09: 593 321	7/7/93 – 16/11/01
Warkworth Town Bridge (M02)	0	R09: 596 323	7/7/93 – 16/11/01
Mahurangi saline			
Warkworth Town Basin – surface (M03) and subsurface (M04)	0, 1	R09: 597 324	7/7/93 – 16/11/01
Dawsons Creek – surface (M05) and subsurface (M06)	0, 1	R09: 640 280	6/5/93 – 16/11/01
Mahurangi Heads – surface (M07) and subsurface (M08)	0, 5	R09: 649 216	2/9/93 – 16/11/01
Tamaki streams			
Otara Creek - East Tamaki Rd (T1)	0	R11: 778 693	9/11/92 – 13/12/01
Pakuranga Creek - Greenmount Drive (T2)	0	R11: 799 725	9/11/92 – 13/12/01
Pakuranga Creek - Guys Rd (T3)	0	R11: 804 727	9/11/92 – 13/12/01
Pakuranga Creek - Botany Rd (T4)	0	R11: 812 747	9/11/92 – 13/12/01
Omaru Creek - Taniwha St (T6)	0	R11: 771 786	9/11/92 – 13/12/01
Otaki Creek – Middlemore Crescent (T7)	0	R11: 747 689	9/11/92 – 13/12/01
Tamaki saline			
No. 7 Buoy (saline site 1)	0, 5, bottom	R11: 799 792 approximate	9/11/92 – 13/12/01
Panmure Basin	0	R11: 758 756[a]	9/11/92 – 15/4/99
Panmure Bridge (saline site 2)	0	R11: 759 754[a]	14/5/99 – 13/12/01
Otara Lake at weir	0	R11: 762 713[a]	16/5/95 – 20/2/01
Upper Waitemata Harbour			
Hobsonville Jetty (UW1)	0, 1	R11: 597 891	22/7/93 – 9/4/01
Lucas Creek (UW2)	0, 1	R10: 588 911	22/7/93 – 9/4/01
Waimarie Road (UW3)	0, 1	R10: 567 907	22/7/93 – 9/4/01
Paremoremo Ski Club (UW4)	0, 1	R10: 562 919	22/7/93 – 9/4/01
Rarawaru Creek (UW5)	0, 1	R10: 549 904	22/7/93 – 9/4/01
Brighams/Rangitopuni Confluence (UW6)	0, 1	R10: 541 909	22/7/93 – 9/4/01
Brighams Creek (1 km from	0, 1	R10: 534 900	22/7/93 – 9/4/01

Site (code)	Depths (m)	Map reference NZMS 260	Monitoring period
confluence) (UW7)			
Rangitopuni Creek (UW8)	0, 1	R10: 534 915	22/7/93 – 9/4/01

3. WATER QUALITY VARIABLES

The water quality variables measured during each sampling run are a combination of physical observations, *in situ* meter readings (Table 3.1), and chemical and biological analysis of collected samples in the laboratory (Table 3.2).

Some observations have not been transcribed to a spreadsheet format and are only documented on ARC field notes, or laboratory notes. These are indicated (*).

Water quality data for the period 1992-present that are the primary focus of this report are underlined.

A description of the reasons for choosing to monitor these variables, their major sources and their impacts on water quality and aquatic life is given elsewhere (ARWB 1982; ARC 1995; Wilcock & Stroud 2000). The chosen variables principally describe water clarity and appearance, nutrient status, biological productivity (in response to nutrient inputs) and physical conditions important for supporting aquatic life. They do not include toxicants, such as heavy metals and organochlorine insecticides.

Table 3.1 Field measurements

(i)	Sample collection time (*)	(NZ Standard Time, 24 h clock)
(ii)	Ambient weather conditions (*)	(Beaufort scale)
(iii)	Ambient water conditions (*)	(Colour, Clarity, Odour)
(iv)	Sample depth	m
(v)	Water temperature	°C
(vi)	Dissolved oxygen	mg/L
(vii)	Dissolved oxygen saturation	%
(viii)	Salinity	ppt
(ix)	Conductivity	mS/m
(x)	Secchi disc depth (saline only)	m
(xi)	Black disk (streams only)	m
(xii)	General comments	

Table 3.2 Laboratory analyses

Presumptive (total) coliforms	(MPN/100 ml)	M, U, T
Faecal coliforms	(MPN/100 ml)	M, U. T
E. coli (freshwater sites only)	(MPN/100 ml)	T
Enterococci (saline sites only)	(cfu/100 ml)	M, T, U
pH	units	M, T, U
Turbidity	(NTU)	M, T, U
Conductivity	(mS/m at 25^{o}C)	M
Suspended solids (Non-filtrable residue)	(mg/L)	M, T, U
Dissolved oxygen saturation	(%)	M, T, U
Biochemical oxygen demand	(mg/L)	M, T, U
Chloride	(mg/L)	M, T, U
Nitrite nitrogen, NO_2-N	(mg/L)	M, T, U
Nitrate nitrogen, NO_3-N	(mg/L)	M, T
Total ammonia nitrogen, NH_4-N	(mg/L)	M, T, U
Total phosphorous, TP	(mg/L)	M, T, U
Dissolved (soluble) reactive phosphorous, DRP	(mg/L)	M, T, U
Salinity	ppt	M, U
Chlorophyll *a*	mg/L	M, T (saline), U

Notes

M = Mahurangi Harbour; T = Tamaki Estuary; U = Upper Waitemata Harbour

Throughout this report we refer to concentrations for many water quality variables (SS, Cl, DO, NH_4-N, NO_2-N, NO_3-N, DRP, TP, BOD) in units of milligrams per litre, or mg/L. Note that mg/L = g/m^3 (g m^{-3}) = parts per million (ppm).

MPN = most probable number; cfu = colony-forming units (APHA 1992)

Presumptive coliform may be approximated to “Total coliform”

Chemical oxygen demand (COD) and total copper, iron and zinc were determined on samples from Pakuranga Creek at Greenmount Drive (only), starting from January 2001, as a cross-reference to landfill Consent monitoring activities.

4 METHODS

4.1 Sampling Procedures

Sampling protocols for the special survey sites are detailed in the following ARC reports for Long Term Baseline Program Coastal/Saline Sampling Protocols: Mahurangi Estuary 2nd Edition (May 1999), Upper Waitemata Harbour 2nd Edition (May 2002), and Tamaki Estuary 3rd Edition (May 2002). Timing of each run is critical, to ensure samples are collected on the same relative stage of the tide, and to ensure that temporal variability is minimised. Samples at all sites are collected within the time window: 08:00 - 12:00, New Zealand Standard Time (NZST).

All samples collected in the surveys were analysed by the Watercare Services Ltd Laboratory at Mangere. Analytical methods utilised in these surveys are described in “Chemical Methods Manual” and “Microbiological and Biological Methods Manual” compiled by Laboratory Services, Watercare Services Ltd. These methods generally follow the "Standard Methods for the Examination of Water and Wastewater 18th Edition (APHA 1992).

4.2 Statistical Analysis

Statistical treatment of the data follows the protocol described in TP30 (ARC 1993), which was that used for the Manukau Harbour saline baseline water quality surveys.

Water quality results are characteristically highly variable because of the wide variety of external factors influencing them. Results were pooled for each site and inspected for normality. Because most of the parameters are non-normally distributed the median has been used in this report as the measure of central tendency (typical value). The median is the middle value (or the mean of two middle values) when data are arranged in increasing or decreasing order of magnitude. Because it is based on rank rather than value, the median is not as easily affected by extreme values as the mean.

All outliers were included in calculation of summary statistics unless they were obvious typographical errors.

Variability in the data has been expressed as the interquartile range divided by the median (IQR/M). This value is the non-parametric equivalent of the coefficient of variance.

Non-parametric statistics have been employed in assessing significant differences between sites and within sites over time. Rank transformation procedures have been used which involves the application of standard parametric statistical analysis to the ranks of the data instead of the data themselves. Greater detail on the use of this technique can be found in Conover and Iman (1981).

Spatial differences between each variable were assessed by non-parametric analysis of variance (ANOVA) to test if the medians were equal. A Kruskal-Wallis test procedure was used to determine if there were any significant ($p<0.05$) differences between the sites. The 5 m depth samples at Mahurangi Heads were not included in the ANOVA because of their close similarity in all respects with the surface samples (site M07).

Comparisons between years for each site were carried out using the same non-parametric approach.

Statistical tests for seasonality and trends over time were performed using non-parametric techniques contained in a statistics program called WQSTAT PLUS (Intelligent Decision Technologies Ltd. 1998).

Data sets were first assessed for seasonality using the Kruskal-Wallis test. Where a seasonal component was found the data set was deseasonalised prior to trend analysis. Trend analysis consisted of the Kendall Tau procedure for data sets of less than five years and the Seasonal Kendall test for larger data sets. For large data sets a Seasonal Kendall slope estimate is calculated which is the equivalent of the Sen Slope Estimate (the non-parametric equivalent of regression analysis).

Summary statistics reported here are as follows: Median (M), IQR/M (%), Normality, Seasonality, Trend, and Slope. Median and IQR/M (%) values for the 2001 year, and Normality, Seasonality, Trend, and Slope values for the entire data set (1992 to December 2001), are given for each water quality variable and each of the sites in Appendices 1-61. Numerical values for trend slopes are only given where $p<0.10$ (at least 90%). All slopes are in concentration units per year (e.g., chloride is in g/L per year).

Until March 1994 UWH sites were taken at both the surface and at a depth of one metre. For a time after this, composite samples were collected for analysis. Currently, samples are taken from the surface and for that reason only surface water quality data from UWH sites has been subjected to statistical analysis.

4.3 Presentation of Data

Data for the last monitoring year (Jan-Dec 2001) along with time-series plots (covering the 1992-2001 period) and summary statistics for each variable at each of the sites are tabulated in Appendices 1-61. Box plots comparing water quality variables between sites within each of the three areas are in Appendix 62. ANOVA comparisons are tabulated in Appendix 63, showing differences in values of water quality variables between sites that are statistically significant ($p < 0.05$). The ANOVA tables rank sites in terms of variable magnitudes.

5. RESULTS

5.1 Water Quality Data

5.1.1 What it tells us

A comprehensive description of each of the water quality variables cited in this report is given in Appendix 64. Black disc and Secchi disc depth data tell us how clear or turbid the water is. This is negatively correlated with turbidity and suspended solids and generally has larger values (i.e. greater clarity) in pristine sites than in sites affected by inputs of sediment (such as urban storm-water from new subdivisions) and the presence of algae caused by high nutrient concentrations.

Chloride and conductivity are not as affected by human activities as the other variables and reflect the relative proportions of freshwater and salt water. Conductivity in freshwater streams is affected by large rainfall events that generate runoff.

Dissolved oxygen (DO) varies diurnally depending upon the amount of plant biomass in the channel producing photosynthetic inputs, the demand on oxygen (BOD) caused by decomposing organic matter, and exchange with the atmosphere produced by turbulence at the air-water interface. Low DO often indicates inputs of degrading organic wastes (such as from sewage and farm effluents), whereas high DO values (> 100%) are attributable to photosynthesis by aquatic plants, including algae. The DO regime dictates the type of aquatic ecosystem that can survive in a given water body.

Presumptive and faecal coliform concentrations indicate the presence of faecal material and the possible presence of pathogenic organisms, such as *Campylobacter, Giardia* cysts and *Cryptospiridium* oocysts.

Ammonia, nitrite and nitrate are indicative of waste inputs from warm-blooded animals, including humans (from sewage effluent). Nitrite (NO_2-N) is a short-lived intermediate for the transformation of ammonia nitrogen (NH_4-N) to nitrate nitrogen (NO_3-N) and is a useful indicator of how recently pollution events may have occurred. High NH_4-N, in concert with elevated pH and temperatures can be inimical for the survival of many aquatic species because of the proportion of the toxic un-ionised NH_3 increases with respect to the more common and much less toxic ammonium ion (NH_4^+) see Appendix 64).

Dissolved reactive phosphorus (DRP) concentration indicates the potential for eutrophication, whereas total phosphorus (TP) includes DRP and algal biomass. TP and DRP levels should decline with distance away from land-based sources, such as streams and discharges from wastewater treatment plants.

Temperature and pH are master variables that affect the biological activity of other pollutants as well as determining habitat quality. Seawater pH is strongly buffered so that small changes indicate either large inputs of freshwater, or faulty measuring technique.

5.1.2 "Less than" or "greater than" values

A number of data are reported as being less than a detection limit (DL) or greater than some (operational) maximum value. The "less than" values have been treated as having half their respective detection limits whereas the "greater than" values have been assigned their upper limit values (e.g., a value of > 2 is taken as being 2). In many cases detection limits are set too high for useful information about water quality of natural waters. For example, a DL of 2 mg/L for BOD is not useful, when the bulk of the data is less than this.

5.2 The Data

5.2.1 Water clarity and suspended solids

Water clarity in Mahurangi Harbour is moderate-good (apart from times when occasional storms mobilise sediments) and typical of estuarine and harbour

waters, with generally low turbidity and SS values. Secchi values are greatest at Mahurangi Heads. Results are similar for Tamaki and UWH sites although historically Rarawaru Creek has had high SS and turbidity values. Median SS values for all harbour sites were about 10 mg/L and were between those of the Waitemata and Manukau sites in the LTB study (Wilcock & Stroud, 2000). Mahurangi sites showed little change with time, but UWH and Tamaki sites had trends of decreasing SS (undoubtedly affected by high values in the mid-90s for Tamaki Estuary). Curiously, Secchi disk depths for UWH trended downwards over 1992-2001, in contrast with the decreasing SS values, although the data is quite variable.

5.2.2 BOD

The majority of samples are recorded as being < 2 mg/L, the operational detection limit of the analytical laboratory, so that long-term medians are recorded here as mostly 1 mg/L (see 5.2.2). Intermittent high values up to 12 mg/L are observed in UWH, and up to 10 mg/L in Mahurangi Harbour, but both water bodies have generally low BOD loadings. Three of the Pakuranga Creek sites in Tamaki Estuary (Greenmount, Guys and Botany) have previously had BOD values of 50 mg/L or more, but have long-term medians of 3.6, 3.3 and 2.3 mg/L, respectively, and medians for 2001 of 1-2 mg/L. BOD values in Tamaki Estuary are trending downwards, whereas the other two water bodies are not changing.

5.2.3 Chloride, conductivity and salinity

Chloride, conductivity and salinity data indicate the degree of mixing of saltwater with freshwater, and hence the consistency of timing of sampling. The results indicate little difference in these values at each site in Mahurangi Harbour, but some variability in UWH and Tamaki Estuary data. Low chloride values in the past may give false impressions of a positive trend if they are not recorded again. Pakuranga Creek at Botany and Otaki Creek at Middlemore have long-term median chlorides of 30 and 60 mg/L, respectively, but have had intermittent values of 10,000 or more mg/L, indicative of their tidal natures.

5.2.4 Dissolved oxygen

The bulk of UWH data is in mg/L and is mostly above 6 mg/L (75% saturation for saline waters), and the overall median for these sites is 7.1 mg/L, or 90% sat, showing that most sites are well oxygenated. Mahurangi sites mostly have

long-term median DO values ≥ 85% sat. Time series show occasional low values (near zero) for the Supply Jetty and Town Bridge (freshwater) sites, while the Town Basin sites have commonly been near 50% sat, even though the long-term medians are 72% (1 m depth) and 82 % (surface). This is indicative of oxygen-demanding organic loads for these sites. ANOVA shows that the difference between the surface and 1 m depth Town Basin sites is statistically significant ($p<0.05$). DO values in Tamaki Estuary are worst for the Pakuranga Creek sites (Greenmount, Guys and Botany) and for Omaru and Otaki Creeks. In these sites values less than 50% sat were not infrequent, although the long-term medians were 71-116%. Supersaturation (values >100%) was evident at the Botany Road site and was undoubtedly a result of photosynthetic activity by plants (see 5.2.8) and the fact that DO measurements were made in daylight. Nighttime measurements would have shown the effects of respiration (low DO) at the Botany Road site. Trend analysis varied for survey areas being positive (increasing DO) in Tamaki Estuary and negative in Mahurangi Harbour, with several sites in both water bodies not having significant trends.

5.2.5 Microbial quality

Total (presumptive) coliform showed useful gradients, declining in value from freshwater sites to saline sites more distant from land, sometimes by 3 orders of magnitude. No significant trends were evident.

Faecal coliform medians in Mahurangi Harbour paralleled the total coliform data by declining from the sites near Warkworth (500-1000 MPN/100 mL) towards the saline sites (1 MPN/100 mL). Trend analysis indicates little change has occurred at most sites in the monitoring period, with the exception being three of the Tamaki sites (Pakuranga Creek-Greenmount and Guys, and Otaki Creek). Median values can be compared with bathing water and shellfishing water guidelines (ANZECC, 2000), which are 150 MPN/100 mL and 14 MPN/100 mL, respectively (Note the precise wording of these guidelines with respect to sampling). Numerous faecal coliform values breached these numerical guideline values. The long-term medians for four Mahurangi sites, two UWH sites and six Tamaki sites exceeded the bathing water guideline value and all but eight sites from all water bodies exceeded the shellfishing water guideline.

Enterococci and *E. coli* levels declined with distance from land sources, in freshwater–saltwater gradient and mostly showed little change with time. New guidelines for marine and recreational waters have been released by Ministry for the Environment (MfE, 2002). Enterococci levels at several sites in

Mahurangi Harbour and Tamaki Estuary frequently breach the Alert/Amber mode, for which a single sample has a value greater than 136 enterococci/100 mL.

5.2.6 N nutrients

Ammonia-N values have been uniformly low in the Mahurangi Harbour and UWH sites, seldom exceeding 0.1 mg/L for all but the Town Basin sites, which were mostly less than 0.2 mg/L. Concentrations of NH_4-N in Tamaki Estuary sites (notably Otara Creek, all three Pakuranga Creek sites and Omaru Creek) have at times greatly exceeded values known to be harmful to fish. The ANZECC (2000) trigger value for protection of 95% of freshwater species is 0.90 mg/L and the corresponding value for 80% species protection is 2.3 mg/L (these values are for total ammonia at pH 8). By comparison a maximum of 6.7 mg/L was recorded on 19-Jan-2000 in Otara Creek. Tamaki data exceeded 1 mg/L on 14 occasions out of a total of 877 observations, but medians at all sites in all three water bodies were below 0.2 mg/L. Trends were mostly minimal or not significant, the exceptions being markedly improving values for the three Tamaki sites (Greenmount, Guys and Otara Creek) that had high values prior to 1998. Ammonia is not now considered to pose a toxic threat to aquatic life in Mahurangi Harbour and UWH, and Tamaki Harbour, on the basis of the medians and trends.

Nitrite-N concentrations in recent years have been close to detection limits and steady. Past levels in Tamaki Estuary have been elevated in Pakuranga Creek-Greenmount (up to 0.885 mg/L) and Guys (14 mg/L) so that downward trends are now evident as concentrations approximate the other sites. These changes may be a response to improvements in reticulation and treatment of wastewater and stormwater.

Nitrate-N concentrations in Mahurangi Harbour were generally moderate-low (<0.5 mg/L) and showing a downward trend with time. Long-term and 2001 median values in Mahurangi Harbour exhibit a gradient of 0.3 mg/L in the upper (freshwater) sites down to <0.01 mg/L at Mahurangi Heads. UWH values were uniformly low and show no significant trend. Long-term and 2001 medians were less than 0.1 mg/L. Tamaki sites had the highest NO_3-N concentrations, with long-term medians ranging from 0.013 mg/L (No. 7 Buoy) to 1.25 mg/L (Otara Creek). Trend analysis shows the data to be strongly seasonal but exhibiting little change over time, as evident from comparison of the 2001 and long-term medians. The maximum value recorded was 5.76 mg/L (Pakuranga Creek-Greenmount on 20-Jul-1994). Nitrate-N levels in some Tamaki Estuary sites are likely to stimulate plant growth that may be

problematic. Nitrate loads enter the estuary in freshwater streams, and presumably originate from terrestrial sources. There is little change in the Tamaki site data with time.

5.2.7 P nutrients

UWH and Mahurangi Harbour sites were uniformly low (medians typically 0.02-0.03 mg/L) with a slight downward trend at many sites. The same is also true for Tamaki estuary sites since 1996. Prior to 1996, concentrations at Pakuranga Creek-Greenmount were commonly above 0.2 mg/L and likely to contribute to estuarine eutrophication. In recent years DRP concentrations at all Tamaki sites were 0.02-0.03 mg/L, with occasional exceptions.

UWH sites had very low median total-P concentrations (0.003-0.006 mg/L) and show little change with time. Mahurangi site medians are about 10 times those in UWH with sites nearest Warkworth (notably the Town Basin sites) having the highest values. Trend analysis indicates decreasing concentrations for the freshwater sites. Total-P concentrations in Tamaki Estuary were higher than the other two water bodies, with long-term medians ranging from 0.05 mg/L for the saline site (No.7 Buoy) to 0.26 mg/L for the freshwater site, Pakuranga Creek-Guys. A trend of decreasing values is evident, indicating less eutrophic conditions.

5.2.8 pH and temperature

Temperatures were as expected at all sites and ANOVA shows little (if any) difference between sites in each of the three water bodies. Occasionally high pH values have been recorded at some Tamaki sites, most notably for Pakuranga Creek at Botany Road where values have exceeded 9. A value of 8.9 was recorded in January 2001 at this site, consistent with a high degree of primary production (plant photosynthetic activity). This is supported by the very high dissolved oxygen values for this site (up to 192% saturated during 2001). Ammonia concentrations at the Botany Road site are uniformly quite low, so that there is not a risk of enhanced toxicity caused by the elevated pH values. Temperature trends for UWH and Mahurangi Harbour sites were mostly unchanging over 1992-2001, whereas most Tamaki Estuary sites had positive (increasing temperature) trends that seem to be mostly as a result of milder winter temperatures. As expected, there was little change in pH at any of the sites.

5.2.9 Chlorophyll *a*

Long-term median concentrations of chlorophyll *a* for all the sampled sites (only No. 7 Buoy was routinely sampled in Tamaki Estuary) were about 0.002-0.004 mg/L and did not exhibit a clear trend pattern.

5.2.10 COD and total Cu, Fe and Zn

These water quality variables were only measured at the Pakuranga Creek – Greenmount site, starting in January 2001. Total copper and zinc concentrations were nearly all below the trigger value for the 95% level of protection of marine species (ANZECC, 2000). There are no guideline values for total iron or for COD. Given the insensitivity of BOD measurements (DL = 2 mg/L) there is some good reason to include COD in the analytical suite because it gives a more meaningful result.

5.3 Between-site Comparisons

Inspection of the box plots (Appendix 62) shows differences between the sites for several variables. There are expected differences in pH, conductivity, chloride and salinity that are a consequence of differences between freshwater and saltwater sites.

5.3.1 Mahurangi Harbour

ANOVA results (Appendix 63) show no significant difference ($p<0.001$) between water quality variables for the Mahurangi Heads surface and 5 m depth sites. Box plots and ANOVA show the Mahurangi Heads sites to have the best visual clarity, with little apparent difference between the other sites. ANOVA for SS and turbidity give conflicting orders with respect to sites other than Mahurangi heads.

Nutrient data shows that generally Dawson's Creek surface and 1 m depth and the Mahurangi Heads sites have the lowest concentrations. Chlorophyll *a* results indicate little difference between sites.

BOD and DO values are generally uniform at all sites other than Warkworth Town Basin, which is clearly more adversely affected than the others.

Bacterial quality varies greatly between sites and there is a clear distinction between the inner four sites (Supply Jetty, Town Bridge and Town Basin

surface) and the outer sites (Dawson's Creek and Mahurangi Heads). This is shown in the ANOVA results, which show the Warkworth Town Basin site to be consistently the worst affected by faecal bacteria.

Distinctions between sites may be made by using the ANOVA rankings from best water quality (low score) to worst water quality (high score) and summing the ranks for variables with significant differences. Rankings for Mahurangi sites were summed for SS, turbidity, DO (% sat), NH_4-N, NO_2-N, NO_3-N, DRP, TP, Total coliform and faecal coliform, with the following result (in order of best to worst)

Mahurangi heads < Dawson's Creek (surface and 1 m) << Town Bridge < Supply Jetty < Town Basin (surface and 1 m)

5.3.2 Upper Waitemata Harbour

Box plots and ANOVA show little difference between sites with respect to temperature, pH, SS, turbidity, BOD, DO, NO_2-N and DRP, and only slight differences in Total-P and chl *a*. Secchi values indicate that the Hobsonville site has better visual clarity than other sites in UWH. Ammonia and nitrate nitrogen values show differences between a group of sites comprising Hobsonville Jetty, Lucas Creek and Waimarie Road, and another group comprising Brigham's creek and Rangitopuni Creek. However, differences between medians are not large and of the three water bodies, UWH has the most uniform water quality.

Bacterial quality is best at Hobsonville Jetty and worst for Rarawaru Creek, Brigham's Creek and Rangitopuni Creek.

Using the ANOVA rankings to compare long-term average water quality between UWH sites yielded the following result (in order of best to worst)

Hobsonville Jetty < Waimarie Road < Brigham's/Rangitopuni confluence ≈ Paremoremo Ski Club < Lucas Creek < Rarawaru Creek < Rangitopuni Creek < Brigham's Creek

5.3.3 Tamaki Estuary

Box plots and ANOVA show little or no significant differences between sites for temperature and Secchi disk (only significant data for one site). Also note that the box plots also include data for No. 7 Buoy bottom waters. Differences

in salinity, chloride, conductivity and pH are as expected for a suite of freshwater and saline sites. BOD values were highest at the Pakuranga – Guys and Botany sites, and Otaki Creek, whereas DO was lowest at Pakuranga – Greenmount.

There was a clear pattern for nutrients and faecal bacteria concentrations, with the freshwater sites (Otara Creek, the three Pakuranga Creek sites, Omaru Creek and Otaki Creek) markedly higher than the saline sites (the No. 7 Buoy sites, Panmure Basin and Panmure Bridge). The limited data set for Otara Lake weir showed that enterococci concentrations were generally intermediate between the more contaminated freshwater sites and the less contaminated saline sites.

Using the ANOVA rankings to compare long-term average water quality between Tamaki sites yielded the following result (in order of best to worst)

No. 7 Buoy (surface and 5m) < Panmure Basin < Otara Creek < Pakuranga Creek – Botany < Otaki Creek < Pakuranga Creek – Guys < Omaru Creek < Pakuranga Creek – Greenmount.

6. SUMMARY AND CONCLUSIONS

The monitoring data for freshwater and saline sites in Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary provides a valuable resource describing three different but important water bodies in the Auckland region. Each water body is being subjected to different kinds of pressure exerted by urban development and increasing population in the region. Monitoring projects such as this serve as a basis for rational decision making by enabling changes over time to be observed continuously.

The data shows that Mahurangi Harbour and UWH to have generally good water quality with improving trends for water clarity. Tamaki freshwater stream sites have extreme high and low values of DO, associated with primary production. Mahurangi Harbour and Tamaki Estuary sites have high faecal bacteria concentrations that probably derive from human activities.

Tamaki Estuary has the worst water quality, as might be expected in terms of its catchment population. It is, however, showing improving trends in SS, DO and NH_4-N concentrations.

ANOVA has been used to compare sites and give an overall ranking, as follows (where sites are ranked from best – lowest rank score – to worst – highest rank score)

Mahurangi Harbour: Mahurangi heads < Dawson's Creek (surface and 1 m) << Town Bridge < Supply Jetty < Town Basin (surface and 1 m)

UWH: Hobsonville Jetty < Waimarie Road < Brigham's/Rangitopuni confluence ≈ Paremoremo Ski Club < Lucas Creek < Rarawaru Creek < Rangitopuni Creek < Brigham's Creek

Tamaki Estuary: No. 7 Buoy (surface and 5m) < Panmure Basin < Otara Creek < Pakuranga Creek – Botany < Otaki Creek < Pakuranga Creek – Guys < Omaru Creek < Pakuranga Creek – Greenmount

This analysis shows that the marine sites furthest from land-based sources of pollution (viz. Mahurangi Heads, Hobsonville jetty and No. 7 Buoy) have the best overall water quality.

7. REFERENCES

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APPENDICES
APPENDIX 1: MAHURANGI HARBOUR – TEMPERATURE

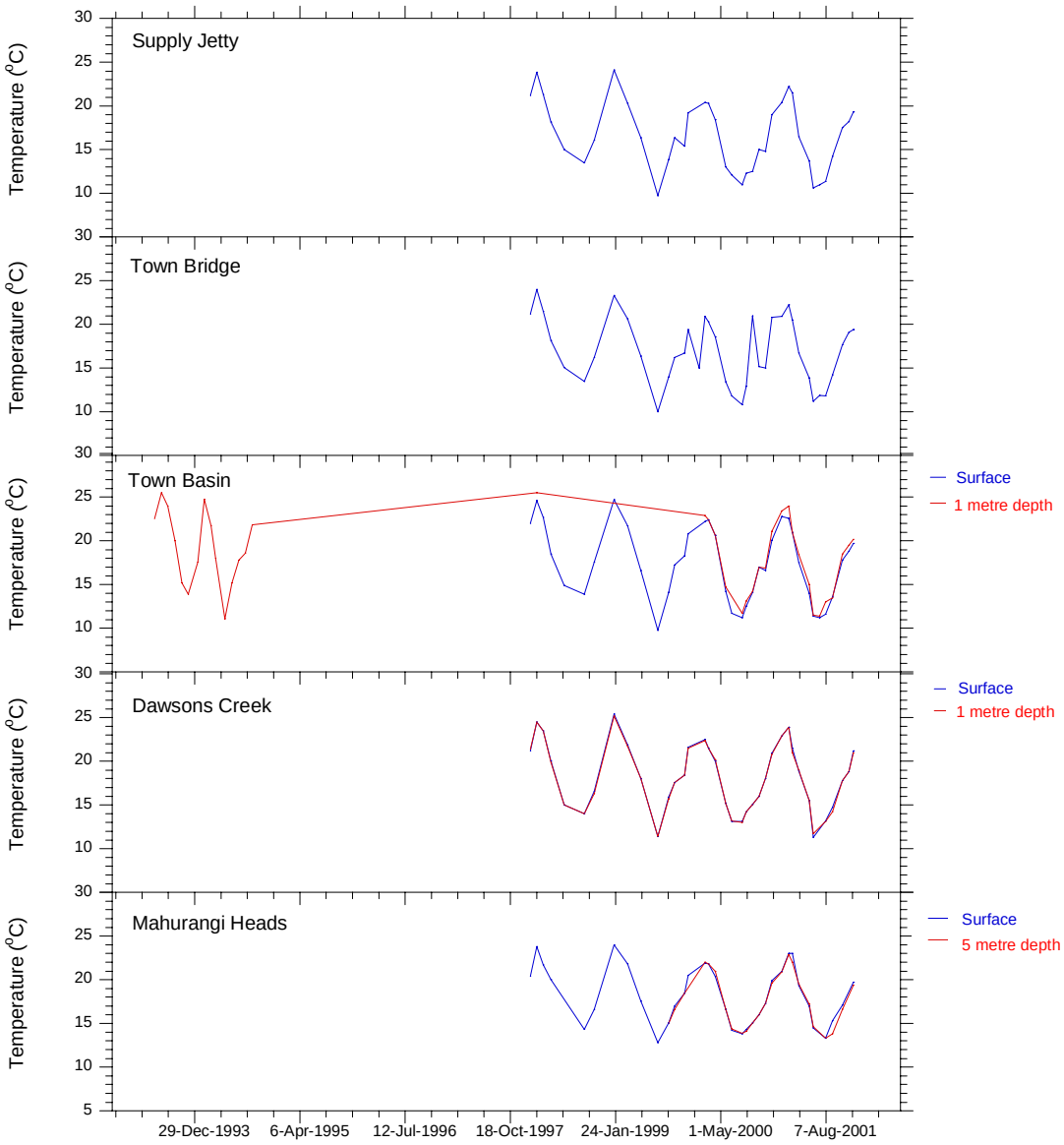
a) Temperature (^{o}C) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	20.4	20.9	22.8	23.4	22.9	22.9	21.0	20.9
26-Feb-01	22.2	22.2	22.6	24.0	23.9	23.9	23.0	22.9
12-Mar-01	21.5	20.5	21.0	21.0	21.5	21.0	23.0	22.0
10-Apr-01	16.5	16.7	17.5	18.4	18.9	19.0	19.3	19.5
25-May-01	13.7	13.9	14.0	15.0	15.5	15.5	17.0	17.2
12-Jun-01	10.6	11.2	11.4	11.5	11.3	11.7	14.5	14.6
10-Jul-01	11.0	11.9	11.2	11.4				
07-Aug-01	11.4	11.8	11.6	13.0	13.2	13.1	13.3	13.3
06-Sep-01	14.2	14.2	13.6	13.5	14.7	14.2	15.3	13.8
18-Oct-01	17.5	17.7	17.8	18.5	17.8	17.8	17.1	16.6
16-Nov-01	18.2	19.1	18.8	19.5	18.8	18.8		
05-Dec-01	19.3	19.4	19.7	20.2	21.2	21.0	19.7	19.4
Median	17	17.2	17.65	18.45	18.8	18.8	18.2	18.3
IQR/Median %	38	36	39	38	33	33	27	30

b) Statistical summary for 1993-2001: Temperature (^{o}C)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	38	39	38	38	37	37	35	23
Median	16.4	16.7	17.6	18.5	18.0	18.0	17.6	17.2
Normality	T	F	T	T	F	F	T	T
Seasonality	Y	Y	Y	Y	Y	Y	Y	Y
Trend	NS	NS	93%	91%	NS	NS	NS	NS
Slope	NS	NS	-0.56	-0.53	NS	NS	NS	NS

c) The graphs on the following pages show temperature measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Temperature (°C)
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 2: MAHURANGI HARBOUR – PH

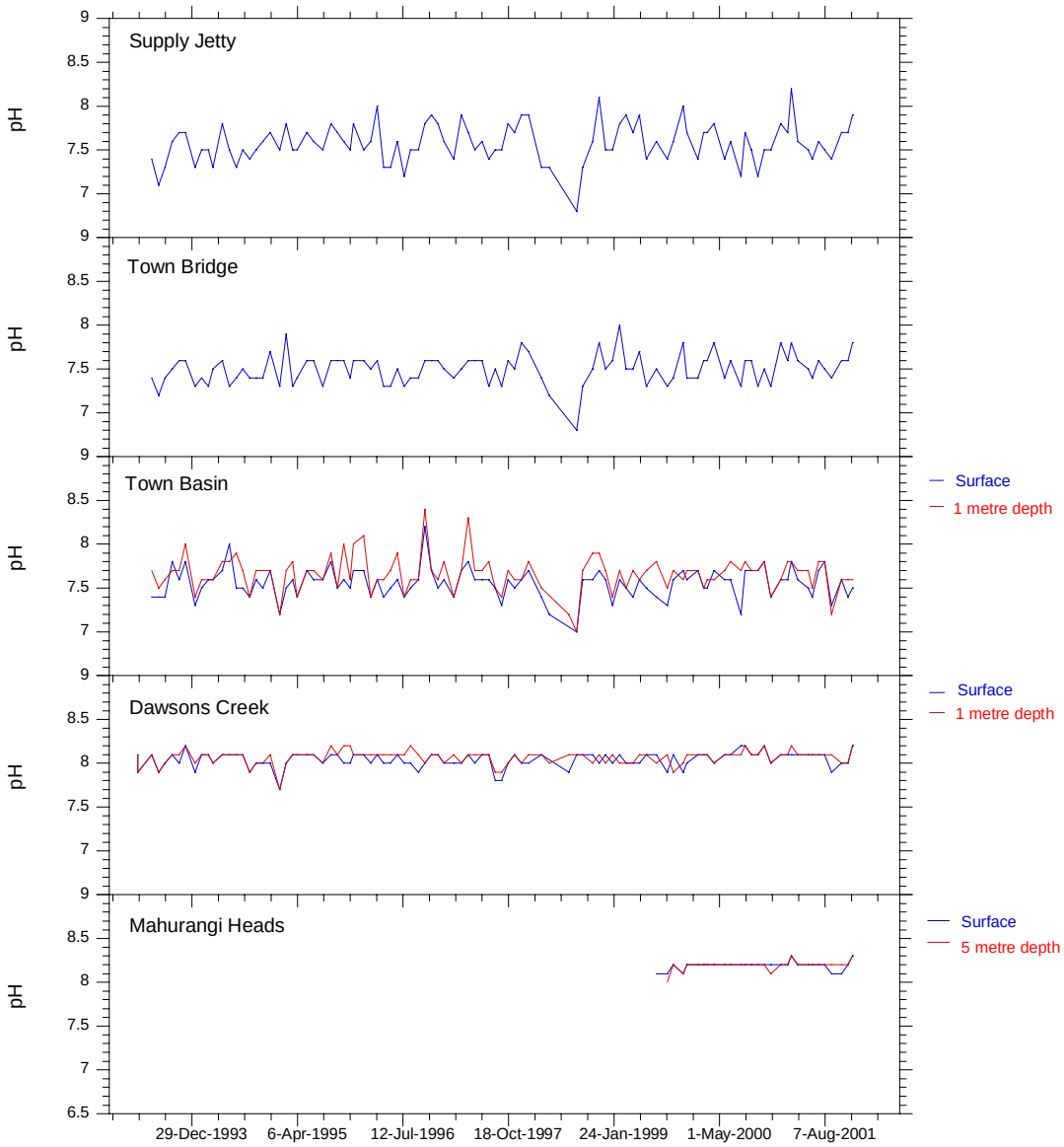
a) pH (units) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	7.8	7.8	7.6	7.6	8.1	8.1	8.2	8.2
26-Feb-01	7.7	7.6	7.6	7.8	8.1	8.1	8.2	8.2
12-Mar-01	8.2	7.8	7.8	7.8	8.1	8.2	8.3	8.3
10-Apr-01	7.6	7.6	7.6	7.7	8.1	8.1	8.2	8.2
25-May-01	7.5	7.5	7.5	7.7	8.1	8.1	8.2	8.2
12-Jun-01	7.4	7.4	7.4	7.5	8.1	8.1	8.2	8.2
10-Jul-01	7.6	7.6	7.7	7.8	8.1	8.1	8.2	8.2
07-Aug-01	7.5	7.5	7.8	7.8	8.1	8.1	8.2	8.2
06-Sep-01	7.4	7.4	7.3	7.2	7.9	8.1	8.1	8.2
18-Oct-01	7.7	7.6	7.6	7.6	8.0	8.0	8.1	8.2
16-Nov-01	7.7	7.6	7.4	7.6	8.0	8.0	8.2	8.2
05-Dec-01	7.9	7.8	7.5	7.6	8.2	8.2	8.3	8.3
Median	7.7	7.6	7.6	7.7	8.1	8.1	8.2	8.2
IQR/Median %	3	2	2	3	0	0	0	0

b) Statistical summary for 1993-2001: pH (units)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	97	97	98	98	29	28
Median	7.6	7.5	7.6	7.7	8.1	8.1	8.2	8.2
Normality	F	F	F	F	F	F	F	F
Seasonality	Y	N	N	N	N	N	N	N
Trend	NS	95%	NS	NS	92%	NS	NS	97%
Slope	NS	0	NS	NS	0	NS	NS	0

c) The graphs on the following pages show pH measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
pH
9
8.5
8
7.5
7
6.5
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 3: MAHURANGI HARBOUR – SUSPENDED SOLIDS

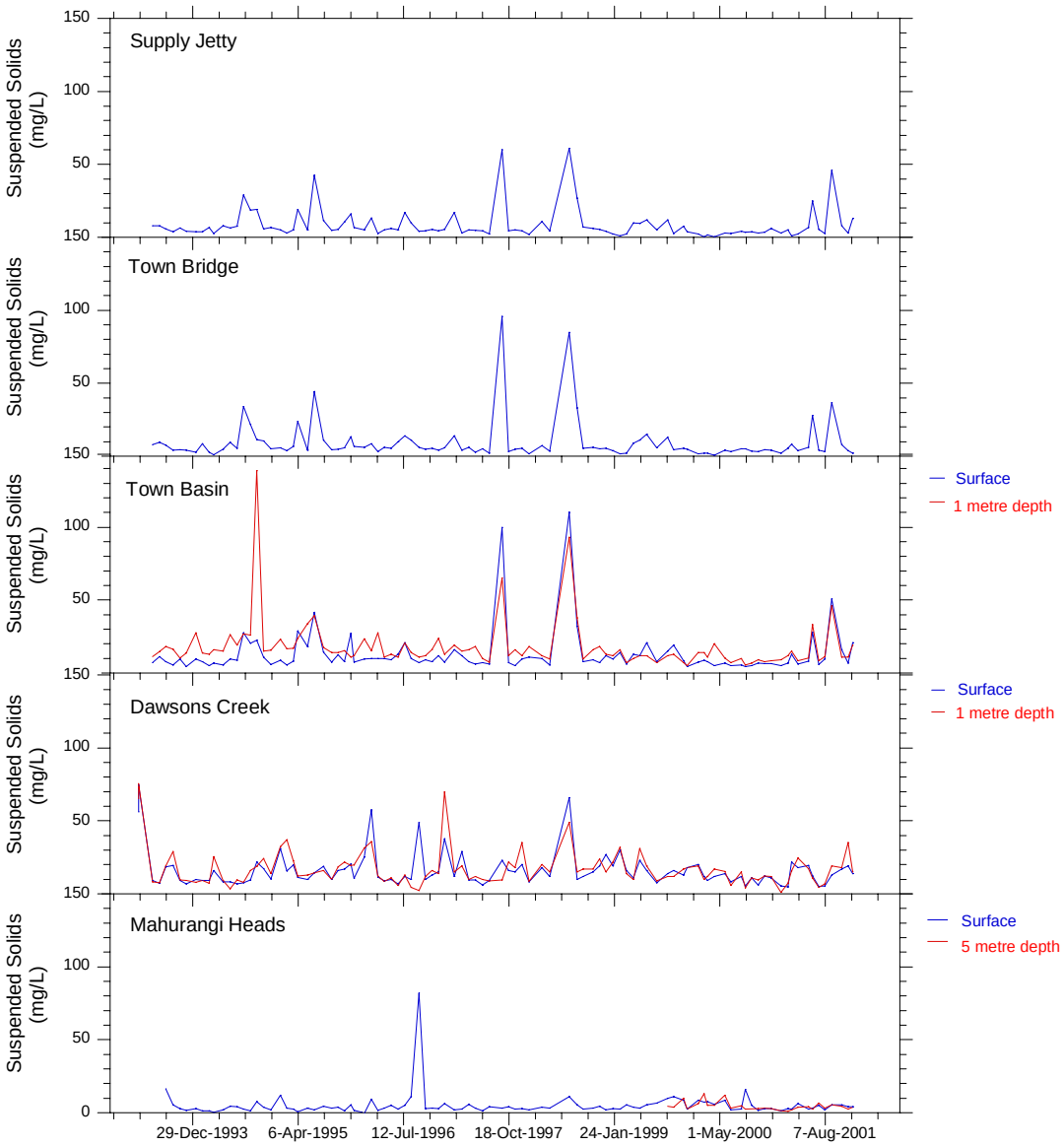
a) Suspended solids (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	3.0	2.1	5.1	9.2	5.7	1.1	1.3	1.4
26-Feb-01	5.1	5.4	6.7	12.0	4.8	7.3	2.7	1.2
12-Mar-01	1.1	8.2	12.9	14.9	22.0	15.7	2.4	2.0
10-Apr-01	2.4	3.9	6.2	8.7	18.1	24.6	6.3	3.6
25-May-01	6.8	6.2	8.1	10.4	19.6	17.3	2.4	4.2
12-Jun-01	25.0	28.0	28.0	33.0	12.2	11.0	3.1	2.4
10-Jul-01	5.4	4.1	6.0	8.6	5.2	4.7	5.0	6.4
07-Aug-01	2.8	3.3	9.7	11.5	5.6	6.7	2.0	3.1
06-Sep-01	46.0	37.0	51.0	46.0	13.0	19.0	5.4	5.6
18-Oct-01	7.9	7.7	16.0	11.0	17.0	18.0	5.5	4.7
16-Nov-01	3.2	3.6	7.0	11.0	19.0	35.0	4.0	2.5
05-Dec-01	13.0	2.2	21.0	19.0	14.0	15.0	4.2	3.8
Median	5.3	4.8	8.9	11.3	13.5	15.4	3.6	3.4
IQR/Median %	119	91	120	52	94	72	76	60

b) Statistical summary for 1993-2001: Suspended solids (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	97	97	98	98	95	28
Median	5.3	5.4	9.0	13.9	12.3	14.7	3.1	3.8
Normality	F	F	F	F	F	F	F	F
Seasonality	Y	N	N	N	N	N	N	N
Trend	100	99	NS	100	NS	NS	96	NS
Slope	-0.39	-0.30	NS	-0.88	NS	NS	0.17	NS

c) The graphs on the following pages show suspended solids measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Suspended Solids (mg/L)
150
100
50
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 4: MAHURANGI HARBOUR – TURBIDITY

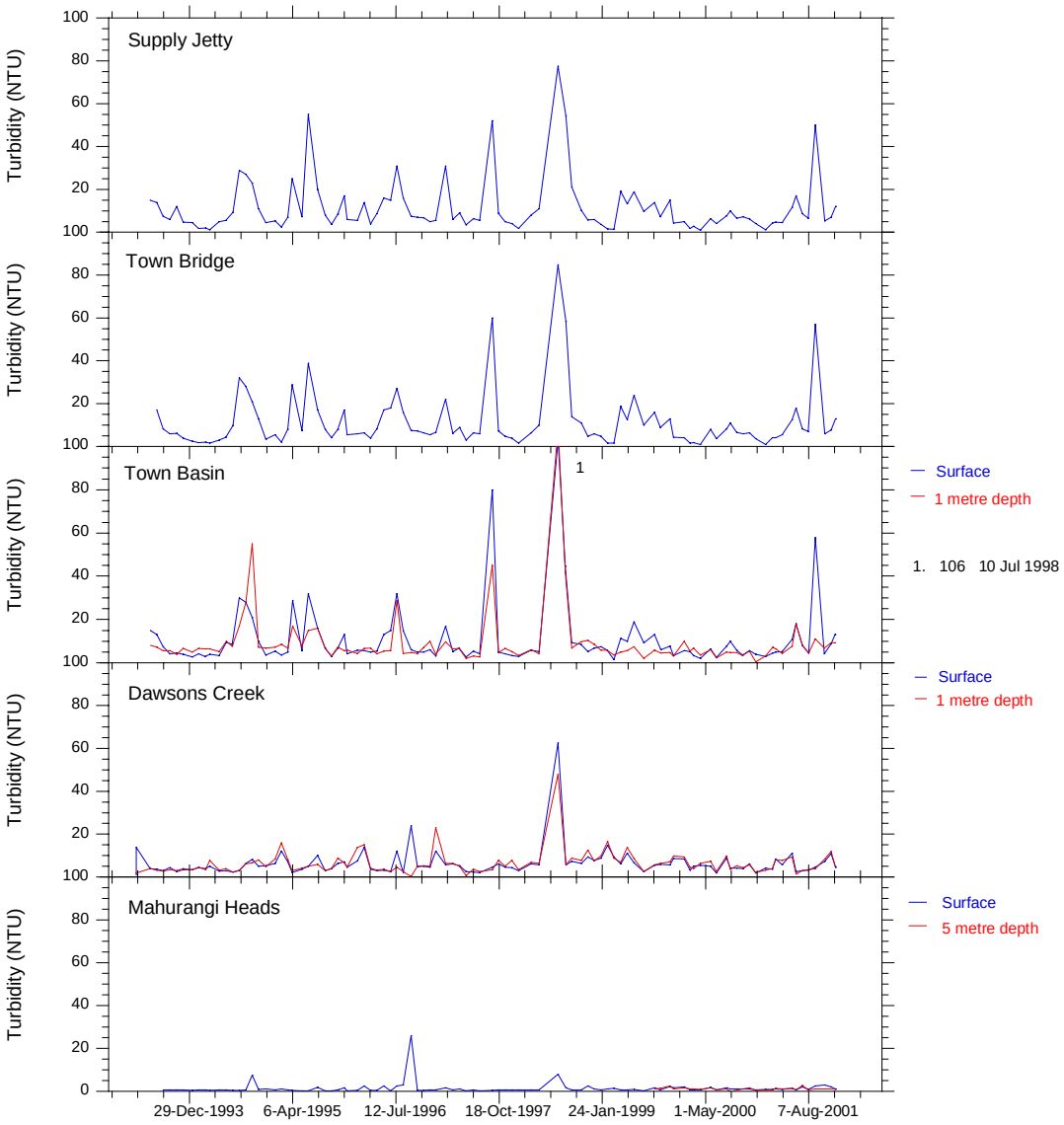
a) Turbidity (NTU) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	1.2	1.0	3.0	3.2	4.1	3.3	1.0	0.7
26-Feb-01	4.3	4.2	4.6	7.2	3.8	3.9	0.9	0.8
12-Mar-01	4.9	4.2	5.0	6.3	8.5	8.0	1.2	1.4
10-Apr-01	4.5	5.5	5.2	4.3	5.7	7.8	0.9	1.1
25-May-01	11.6	12.6	10.8	7.8	11.3	9.3	1.4	1.4
12-Jun-01	17.0	18.0	18.0	18.0	2.4	1.4	0.6	0.8
10-Jul-01	8.7	8.2	8.1	8.1	3.1	3.0	2.0	2.7
07-Aug-01	6.6	7.0	4.5	4.6	3.3	3.5	1.0	0.7
06-Sep-01	50.0	57.0	58.0	11.0	4.6	3.9	2.6	1.2
18-Oct-01	5.2	5.9	4.2	6.7	7.2	8.5	2.9	1.3
16-Nov-01	7.1	7.7	8.8	9.3	11.0	11.8	2.1	1.3
05-Dec-01	12.0	13.0	13.0	9.3	4.5	4.6	1.2	0.9
Median	6.9	7.4	6.6	7.5	4.6	4.3	1.2	1.1
IQR/Median %	101	103	102	46	85	110	88	48

b) Statistical summary for 1993-2001: Turbidity (NTU)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	96	97	97	98	98	95	28
Median	7.1	6.9	5.9	6.3	5.1	5.1	0.7	1.2
Normality	F	F	F	F	F	F	F	F
Seasonality	Y	Y	N	N	N	N	N	N
Trend	NS	NS	NS	91	NS	94	100	NS
Slope	NS	NS	NS	-0.16	NS	0.19	0.06	NS

c) The graphs on the following pages show turbidity measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Turbidity (NTU)
0
20
40
60
80
100
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
1
Surface
1 metre depth
1. 106 10 Jul 1998
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 5: MAHURANGI HARBOUR – SECCHI DISK

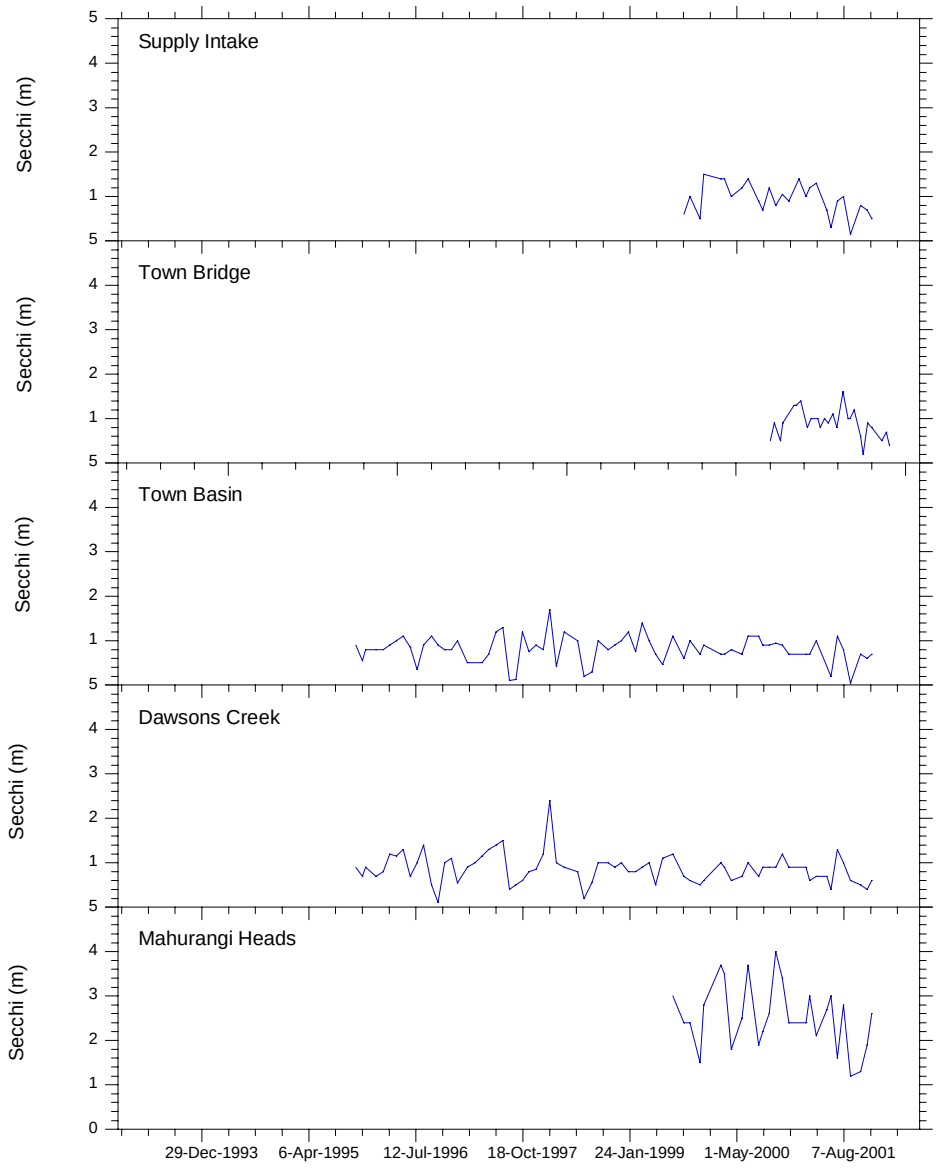
a) Secchi disk (m) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	1.40	1.60	0.70		1.00		3.00	
26-Feb-01	1.00	1.00	0.70		0.90		2.40	
12-Mar-01	1.20	1.00	0.70		0.60		3.00	
10-Apr-01	1.30	1.20	1.00		0.70		2.10	
25-May-01	0.70	0.60	0.70		0.70		2.70	
12-Jun-01	0.30	0.20	0.20		0.40		3.00	
10-Jul-01	8.70	8.10	8.10		3.10		2.70	
07-Aug-01	1.00	0.80	0.80		1.00		2.80	
06-Sep-01	0.15		0.05		0.60		1.20	
18-Oct-01	0.80	0.50	0.70		0.50		1.30	
16-Nov-01	0.70	0.70	0.60		0.40		1.90	
05-Dec-01	0.50	0.40	0.70		0.60		2.60	
Median	0.9	0.8	0.7		0.7		2.7	!
IQR/Median %	64	69	7		54		30	

b) Statistical summary for 1993-2001: Secchi depth (m)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	27	26	69	4	71	4	27	2
Median	1.0	0.9	0.8	0.7	0.9	1.0	2.5	2.6
Normality	T	F	F	F	T	T	T	T
Seasonality	N	Y	N	INS	N	INS.	N	INS.
Trend	NS	NS	NS	INS.	90%	INS.	NS	INS.
Slope	NS	NS	NS	INS.	-0.040	INS.	NS	INS.

c) The graphs on the following pages show Secchi disk measurements from January 1993 to December 2001 (where data available).


Supply Intake
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Secchi (m)
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 6: MAHURANGI HARBOUR – CHLORIDE

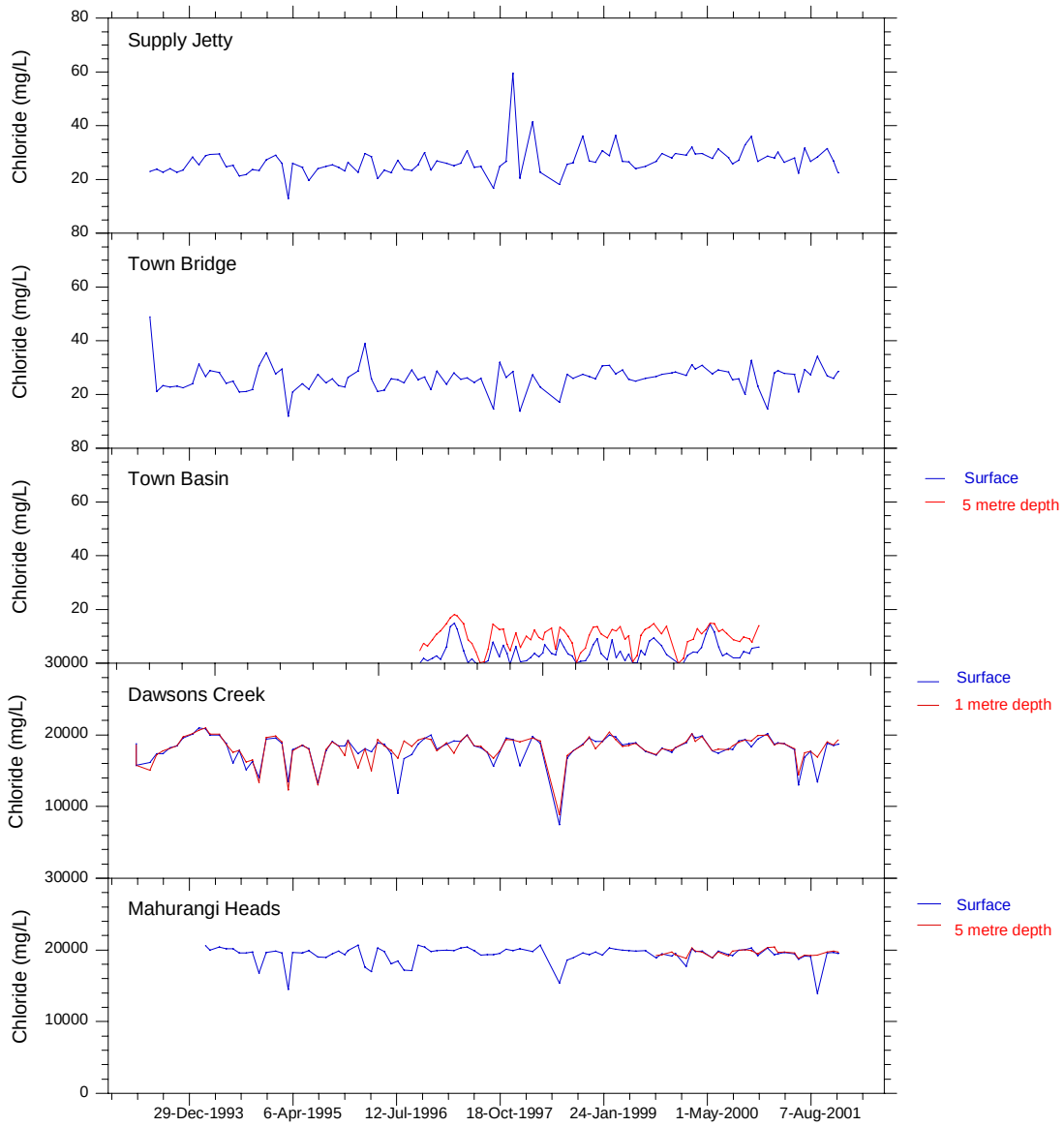
a) Chloride (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	28.7	14.6	5697	12188	20158	20005	20297	20351
26-Feb-01	28.0	28.0	4032	9757	18718	18664	19364	20396
12-Mar-01	30.2	29.0	77.0	11694	18930	18829	19459	19734
10-Apr-01	26.5	27.8	6.63	10963	18763	18734	19646	19734
25-May-01	28.0	27.4	1420	8398	17970	18116	19462	19550
12-Jun-01	22.4	20.9	89.4	1901	13020	14496	18675	18832
10-Jul-01	31.7	29.3	2143	7318	16956	17562	19180	19296
07-Aug-01	26.8	27.3	5626	9789	17775	17761	19111	19221
06-Sep-01	28.4	34.3	62.9	3724	13434	16944	13951	19281
18-Oct-01	31.6	26.9	5638	11153	18822	18998	19571	19732
16-Nov-01	27.0	26.0	3256	10182	18543	18666	19645	19820
05-Dec-01	22.6	28.6	1758	7155	18706	19330	19536	19722
Median	28.0	27.6	1951	9773	18625	18665	19461	19727
IQR/Median %	8	7	223	38	6	6	2	2

b) Statistical summary for 1993-2001: Chloride (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	98	98	99	99	90	28
Median	26.4	26.4	3435	9924	18500	18500	19626	19707
Normality	F	F	F	T	F	F	F	T
Seasonality	N	N	Y	Y	Y	Y	Y	N
Trend	100%	99%	NS	NS	NS	NS	92%	NS
Slope	0.56	0.43	NS	NS	NS	NS	-48	NS

c) The graphs on the following pages show chloride measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Chloride (mg/L)
80
60
40
20
30000
20000
10000
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
5 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 7: MAHURANGI HARBOUR – SALINITY

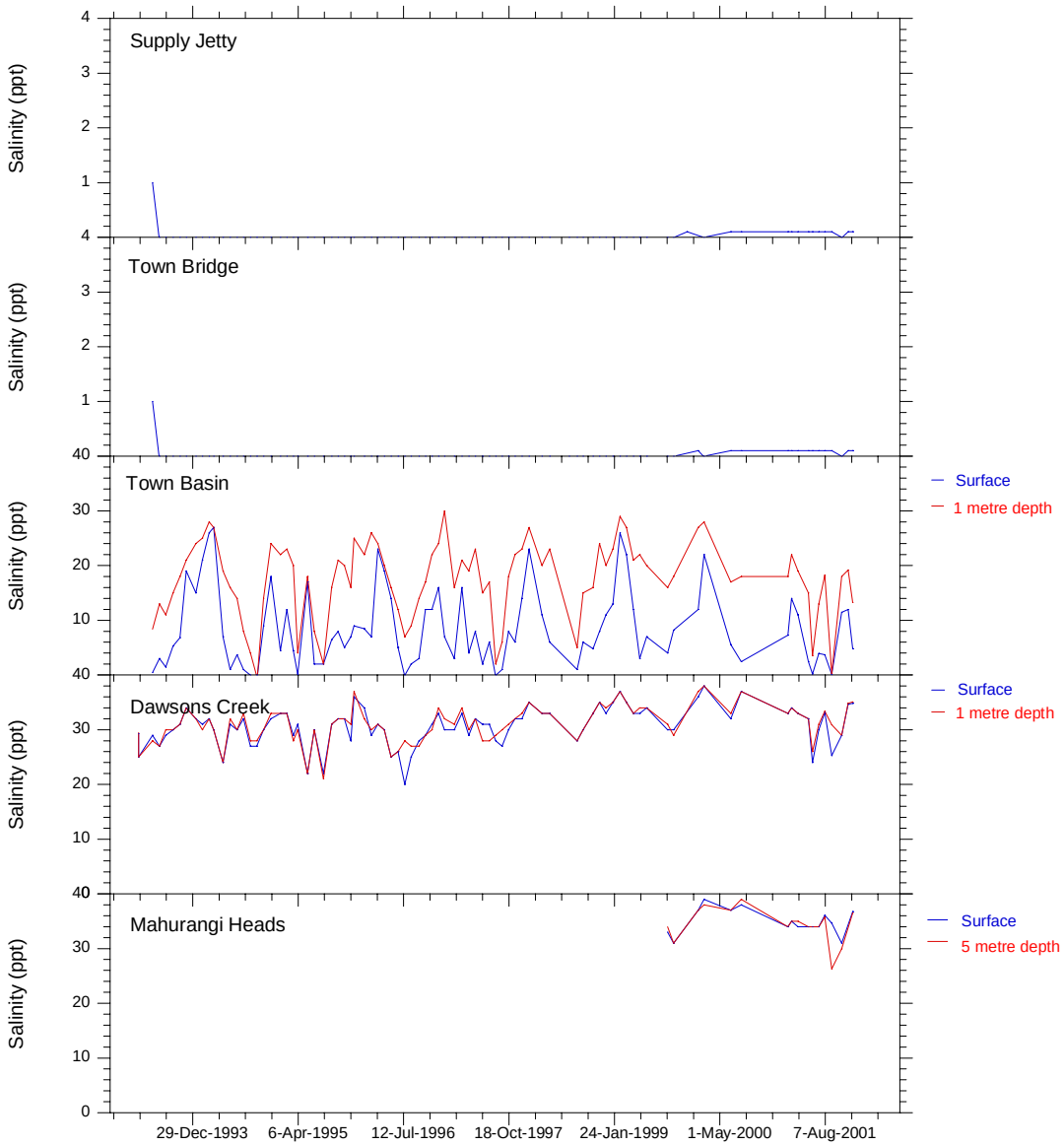
a) Salinity (ppt) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01								
26-Feb-01	0.1	0.1	7	18	33	33	34	34
12-Mar-01	0.1	0.1	14	22	34	34	35	35
10-Apr-01	0.1	0.1	11	19	33	33	34	35
25-May-01	0.1	0.1	3	15	32	32	34	34
12-Jun-01	0.1	0.1	0.2	4	32	32	34	35
10-Jul-01	0.1	0.1	4	13	30	31	34	34
07-Aug-01	0.1	0.1	4	18	33	33	36	36
06-Sep-01	0.1	0.1	0.1	0.3	25	31	26	35
18-Oct-01	0.1	0.1	12	18	29	29	30	31
16-Nov-01	0.1	0.1	12	19	35	35	36	36
05-Dec-01	0.1	0.1	5	13	35	35	37	37
Median	0.1	0.1	5	18	33	33	34	35
IQR/Median %	0	0	169	31	8	6	4	4

b) Statistical summary for 1993-2001: Salinity (ppt)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	86	86	85	85	86	86	16	16
Median	0	0	7	18	31	31	34	34
Normality	F	F	F	T	T	F	T	F
Seasonality	N	N	Y	Y	Y	Y	INS.	INS.
Trend	100%	100%	NS	NS	100%	100%	INS.	INS.
Slope	0	0	NS	NS	0.43	0.50	INS.	INS.

c) The graphs on the following pages show salinity measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Salinity (ppt)
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 8: MAHURANGI HARBOUR – CONDUCTIVITY

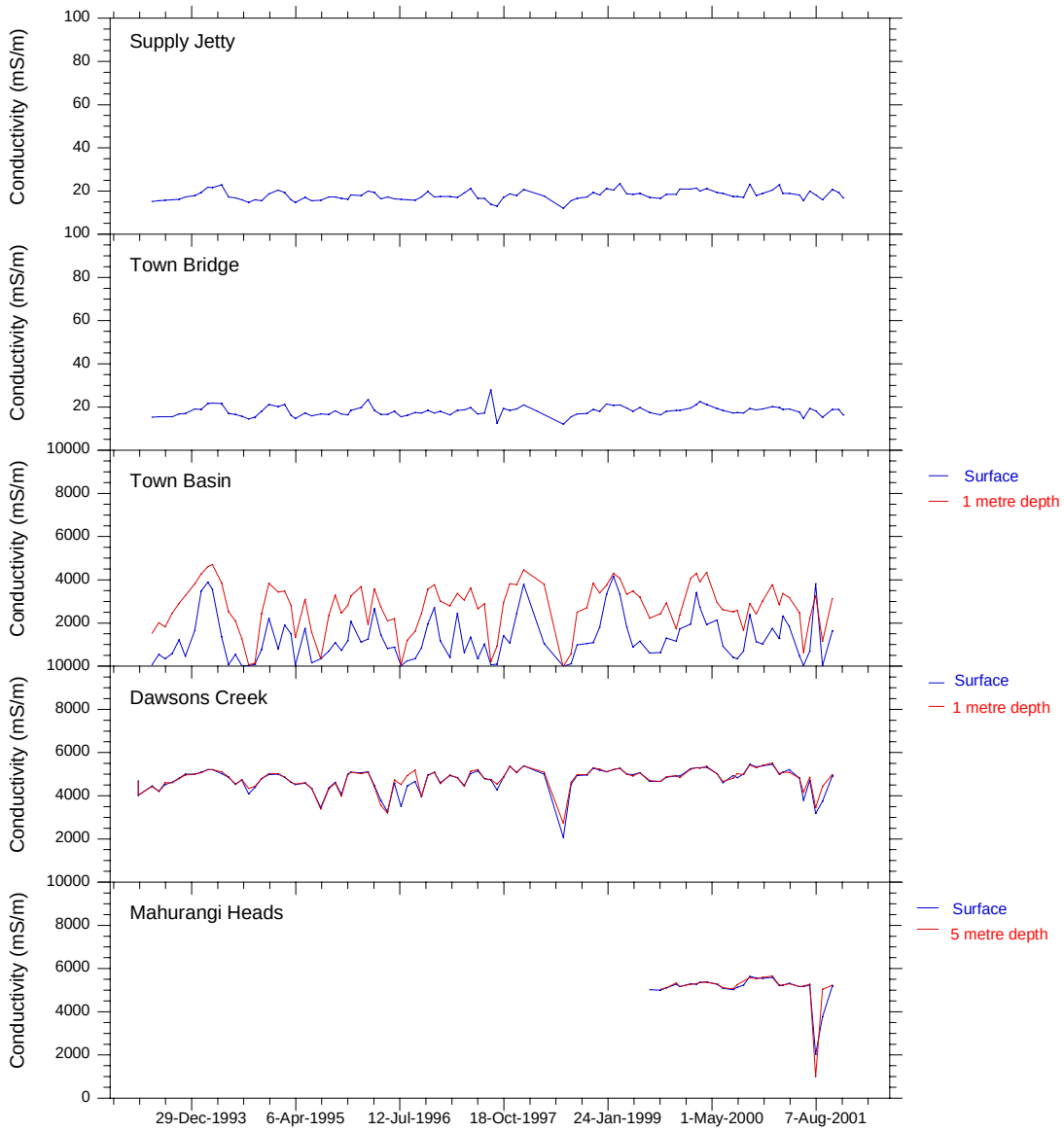
a) Conductivity (mS/m) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	20.5	20.3	1754	3778	5460	5526	5592	5663
26-Feb-01	22.9	19.9	1282	2841	5040	4978	5205	5226
12-Mar-01	18.9	18.9	2324	3367	5102	5102	5225	5236
10-Apr-01	18.9	19.2	1837	3184	5208	5101	5325	5324
25-May-01	18.2	17.8	479	2472	4834	4834	5156	5171
12-Jun-01	15.4	14.9	39.6	642	3786	4168	5168	5182
10-Jul-01	20.1	19.4	711	2212	4707	4865	5234	5269
07-Aug-01	18.1	18.1	3810	3285	3195	3448	2038	1004
06-Sep-01	16.0	15.3	27.7	1149.0	3754	4434	3782	5056
18-Oct-01	20.7	18.9	1647	3133	4907	4987	5179	5227
16-Nov-01	19.3	18.9						
05-Dec-01	16.8	16.5						
Median	18.9	18.9	997	2657	4771	4850	5174	5204
IQR/Median %	13	1775	174	82	30	21	36	23

b) Statistical summary for 1993-2001: Conductivity (mS/m)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	95	95	97	96	96	97	26
Median	17.6	18.0	1090	2880	4890	4920	5220	5240
Normality	T	T	F	T	F	F	F	F
Seasonality	Y	Y	Y	Y	Y	Y	Y	Y
Trend	100%	100%	91%	NS	100%	100%	NS	NS
Slope	0.31	0.24	57.1	NS	52.1	52.8	NS	NS

c) The graphs on the following pages show conductivity measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Conductivity (mS/m)
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 9: MAHURANGI HARBOUR – BIOCHEMICAL OXYGEN DEMAND

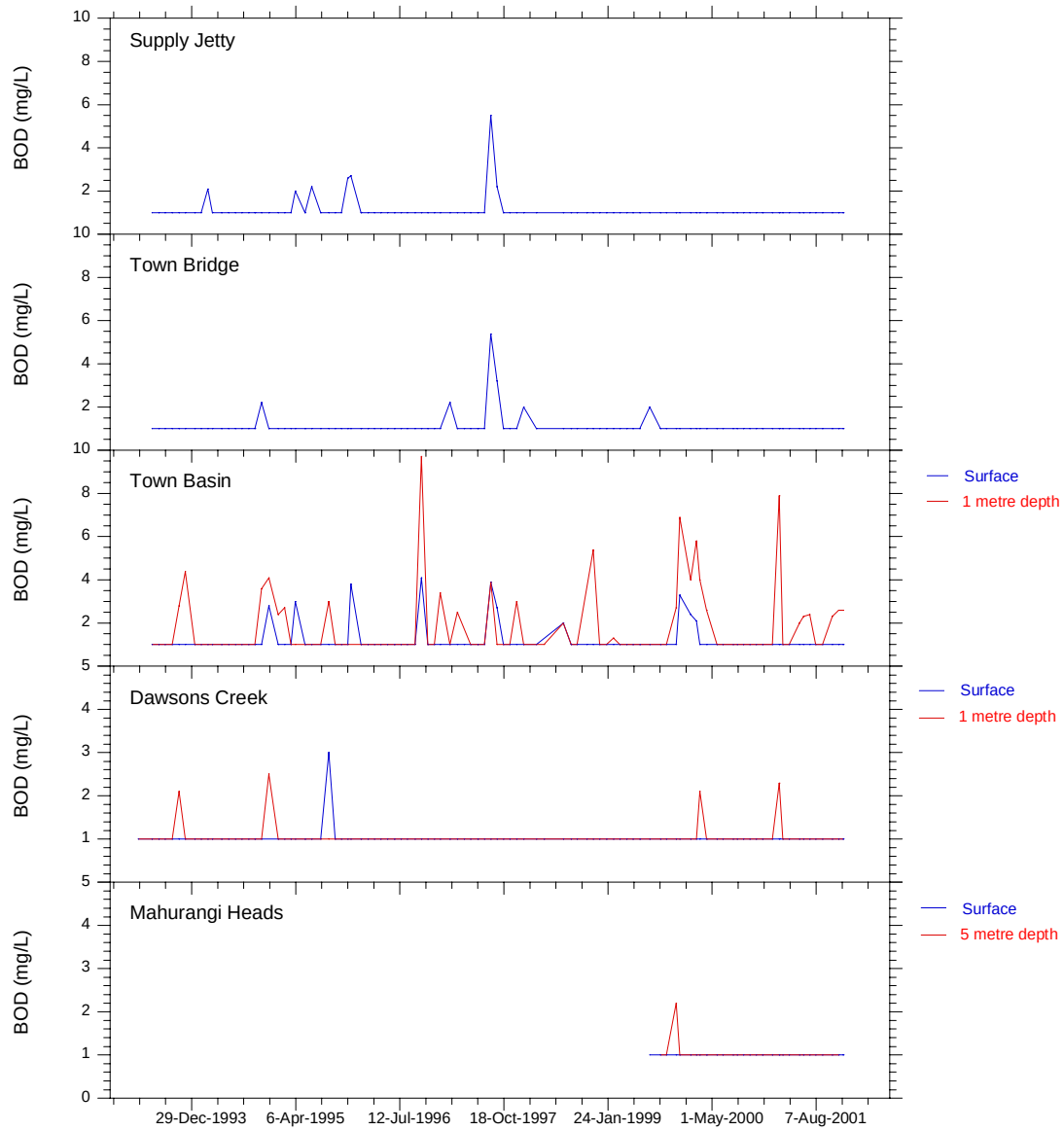
a) BOD (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	<2	<2	<2	<2	<2	<2	<2	<2
26-Feb-01	<2	<2	<2	7.9	<2	2.3	<2	<2
12-Mar-01	<2	<2	<2	<2	<2	<2	<2	<2
10-Apr-01	<2	<2	<2	<2	<2	<2	<2	<2
25-May-01	<2	<2	<2	2.0	<2	<2	<2	<2
12-Jun-01	<2	<2	<2	2.3	<2	<2	<2	<2
10-Jul-01	<2	<2	<2	2.4	<2	<2	<2	<2
07-Aug-01	<2	<2	<2	<2	<2	<2	<2	<2
06-Sep-01	<2	<2	<2	<2	<2	<2	<2	<2
18-Oct-01	<2	<2	<2	2.3	<2	<2	<2	<2
16-Nov-01	<2	<2	<2	2.6	<2	<2	<2	<2
05-Dec-01	<2	<2	<2	2.6	<2	<2	<2	<2
Median	1.0	1.0	1.0	2.2	1.0	1.0	1.0	1.0
IQR/Median %	0	0	0	67	0	0	0	0

b) Statistical summary for 1993-2001: BOD (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	97	95	98	99	29	28
Median	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Normality	F	F	F	F	F	F	F	F
Seasonality	N	N	N	Y	N	N	N	N
Trend	94%	NS	NS	90%	NS	NS	NS	NS
Slope	0	0	0	0	0	0	0	0

c) The graphs on the following pages show BOD measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
BOD (mg/L)
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 10: MAHURANGI HARBOUR – DISSOLVED OXYGEN % SATURATION

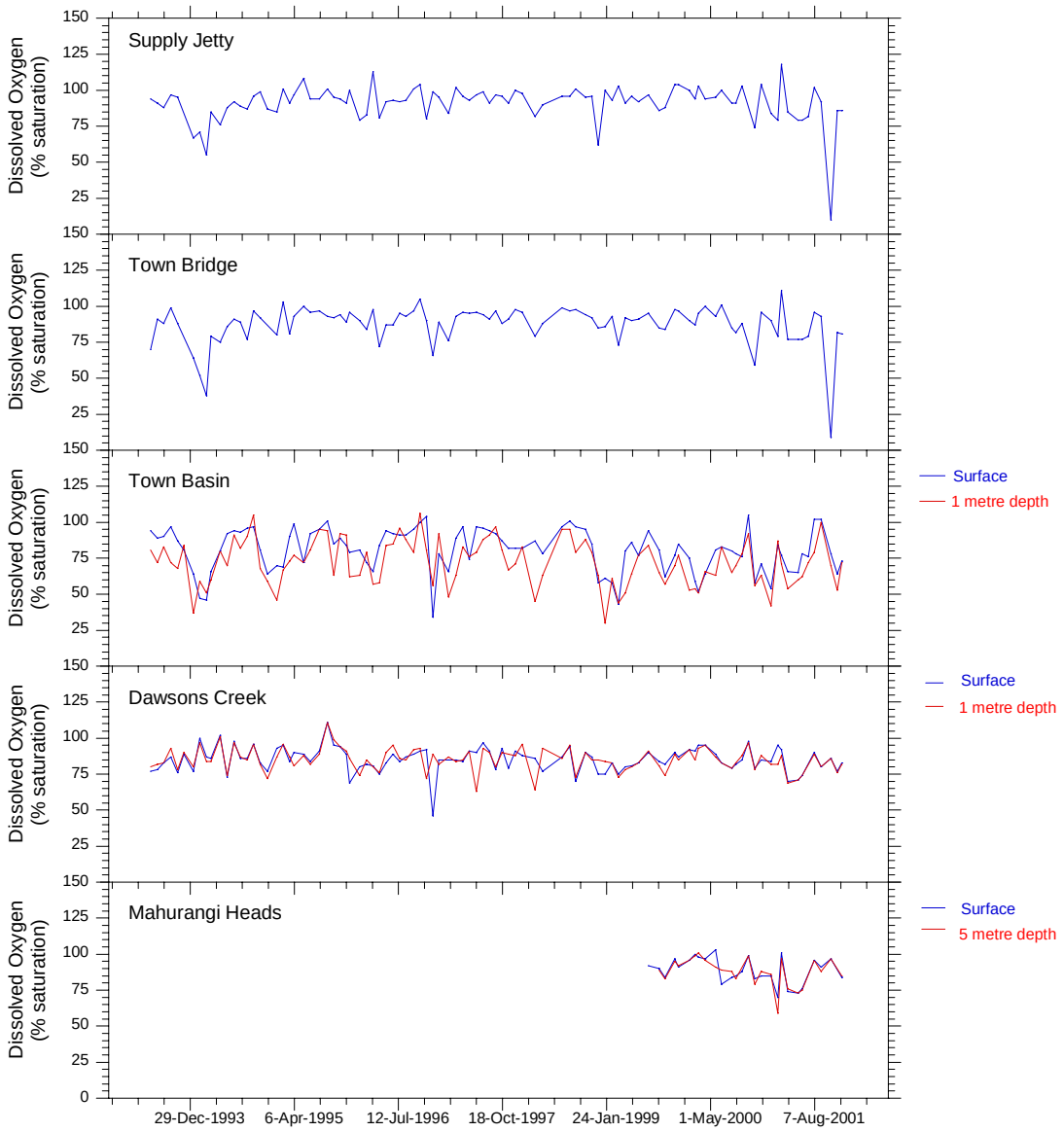
a) Dissolved oxygen (% saturation) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	84	90	54	42	84	82	85	86
26-Feb-01	79	79	84	87	95	82	70	59
12-Mar-01	118	111	77	71	92	8	101	97
10-Apr-01	85	77	66	54	70	69	74	76
25-May-01	79	77	65	60	71	71	73	76
12-Jun-01	79	77	78	62	74	74	76	75
10-Jul-01	82	79	76	72				
07-Aug-01	102	96	102	79	90	89	96	96
06-Sep-01	92	93	102	100	80	80	91	97
18-Oct-01	10	9	78	70	86	86	97	97
16-Nov-01	86	82	64	53	77	76		
05-Dec-01	86	81	73	72	83	82	84	85
Median	85	80	77	71	83	80	85	86
IQR/Median %	10	17	18	22	15	12	24	24

b) Statistical summary for 1993-2001: Temperature (^{o}C)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	95	98	98	97	97	27	26
Median	93	91	82	72	86	85	90	88.5
Normality	F	F	T	T	T	T	T	T
Seasonality	N	N	Y	Y	N	N	N	N
Trend	NS	NS	96%	95%	NS	90%	NS	NS
Slope	NS	NS	-1.08	-1.06	NS	-0.60	NS	NS

c) The graphs on the following pages show dissolved oxygen (% saturation) measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Dissolved Oxygen (% saturation)
150
125
100
75
50
25
0
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 11: MAHURANGI HARBOUR – AMMONIA NITROGEN

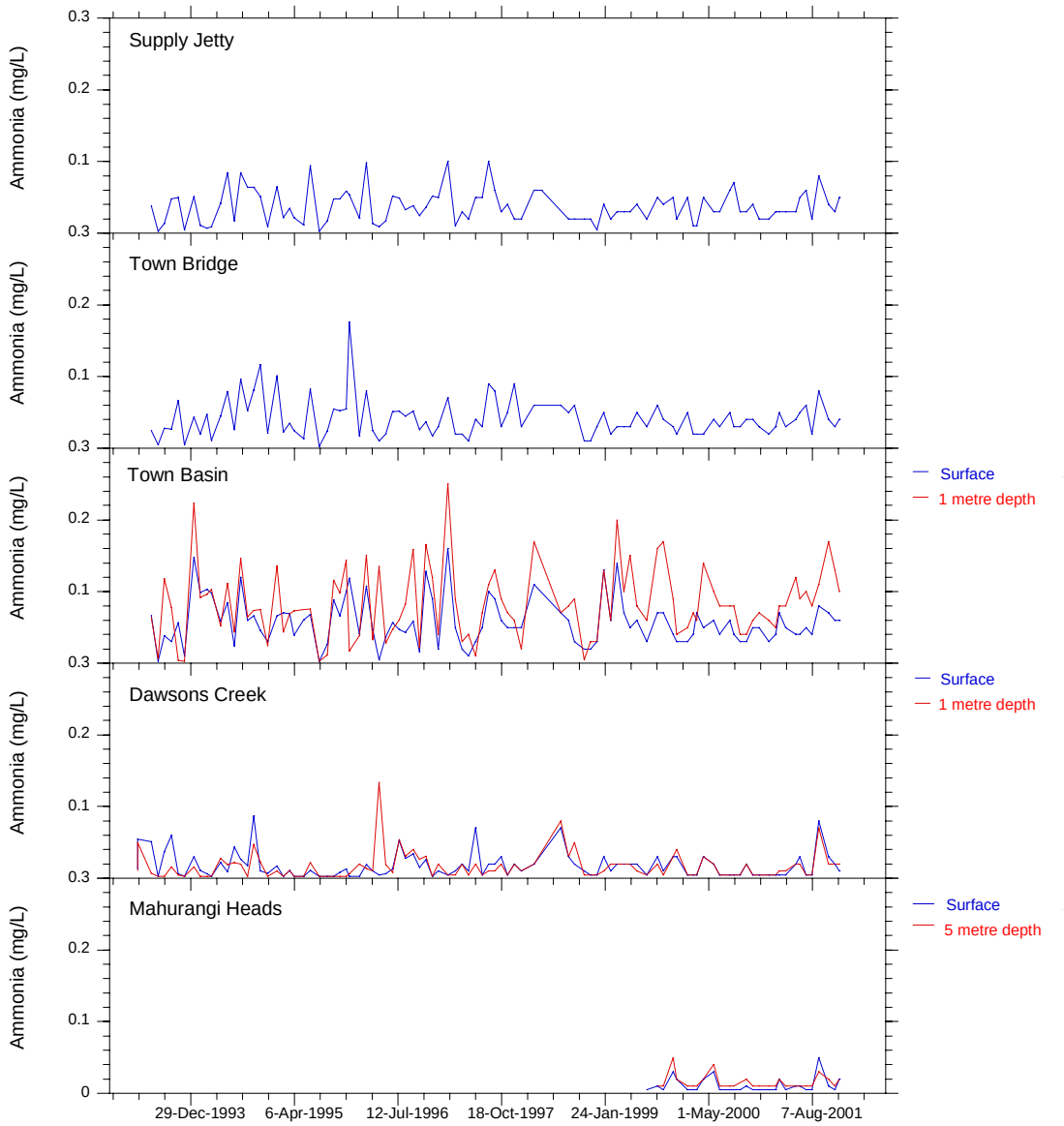
a) Ammonia nitrogen (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.02	0.02	0.03	0.06	0.005	0.005	0.005	0.005
26-Feb-01	0.03	0.03	0.04	0.05	0.005	0.005	0.005	0.005
12-Mar-01	0.03	0.05	0.07	0.08	0.005	0.01	0.02	0.02
10-Apr-01	0.03	0.03	0.05	0.08	0.005	0.01	0.005	0.005
25-May-01	0.03	0.04	0.04	0.12	0.02	0.02	0.01	0.01
12-Jun-01	0.05	0.05	0.04	0.09	0.03	0.02	0.01	0.005
10-Jul-01	0.06	0.06	0.05	0.10	0.005	0.005	0.005	0.005
07-Aug-01	0.02	0.02	0.04	0.08	0.005	0.005	0.005	0.005
06-Sep-01	0.08	0.08	0.08	0.11	0.08	0.07	0.05	0.03
18-Oct-01	0.04	0.04	0.07	0.17	0.03	0.02	0.01	0.02
16-Nov-01	0.03	0.03	0.06	0.13	0.02	0.02	0.005	0.005
05-Dec-01	0.05	0.04	0.06	0.10	0.01	0.02	0.02	0.02
Median	0.030	0.040	0.050	0.095	0.008	0.015	0.008	0.005
IQR/Median %	67	50	45	34	233	100	100	300

b) Statistical summary for 1993-2001: Ammonia nitrogen (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	97	97	98	98	29	28
Median	0.030	0.035	0.050	0.078	0.010	0.010	0.005	0.010
Normality	F	F	F	T	F	F	F	F
Seasonality	N	N	N	N	Y	N	N	N
Trend	NS	NS	NS	92%	NS	90%	NS	NS
Slope	NS	NS	NS	0.0037	NS	0.003	NS	NS

c) The graphs on the following pages show ammonia nitrogen measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Ammonia (mg/L)
0.3
0.2
0.1
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 12: MAHURANGI HARBOUR – NITRITE NITROGEN

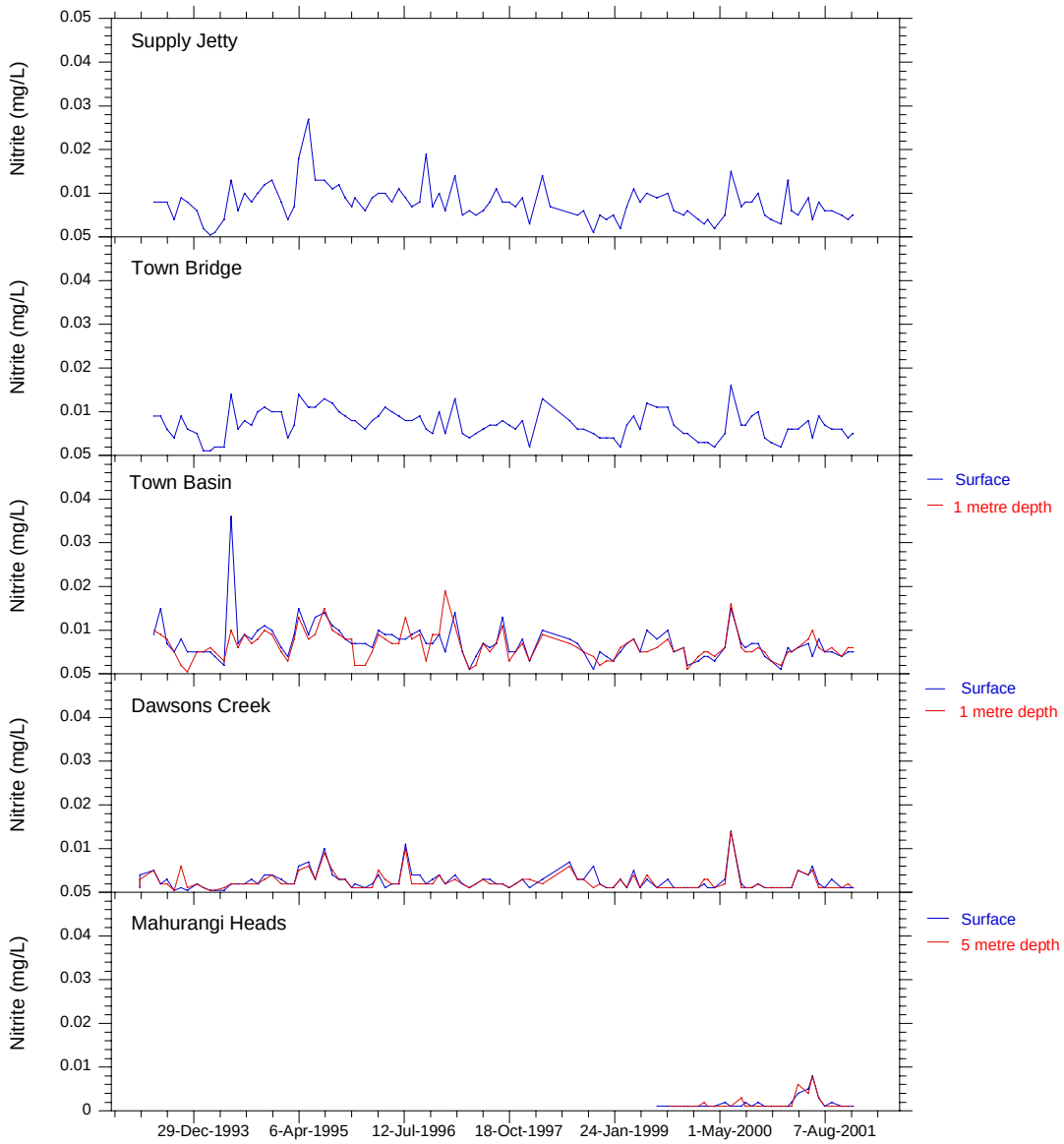
a) Nitrite nitrogen (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.003	0.001	0.001	0.002	0.001	0.001	0.001	0.001
26-Feb-01	0.013	0.006	0.005	0.001	0.001	0.001	0.001	0.001
12-Mar-01	0.006	0.006	0.005	0.002	0.001	0.001	0.002	0.001
10-Apr-01	0.005	0.006	0.006	0.006	0.005	0.005	0.004	0.006
25-May-01	0.009	0.008	0.007	0.008	0.004	0.004	0.005	0.004
12-Jun-01	0.004	0.004	0.004	0.010	0.006	0.005	0.008	0.008
10-Jul-01	0.008	0.009	0.008	0.006	0.002	0.001	0.003	0.003
07-Aug-01	0.006	0.007	0.005	0.005	0.001	0.001	0.001	0.001
06-Sep-01	0.006	0.006	0.005	0.006	0.003	0.001	0.002	0.001
18-Oct-01	0.005	0.006	0.005	0.006	0.003	0.001	0.002	0.001
16-Nov-01	0.004	0.004	0.005	0.006	0.001	0.002	0.001	0.001
05-Dec-01	0.005	0.005	0.005	0.006	0.001	0.001	0.001	0.001
Median	0.006	0.006	0.005	0.006	0.002	0.001	0.002	0.001
IQR/Median %	32	25	5	29	150	150	113	225

b) Statistical summary for 1993-2001: Nitrite nitrogen (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	97	97	97	98	98	29	28
Median	0.007	0.007	0.007	0.006	0.002	0.002	0.001	0.001
Normality	T	F	F	F	F	F	F	F
Seasonality	Y	Y	Y	Y	Y	Y	Y	Y
Trend	100%	100%	100%	98%	95%	99%	95%	NS
Slope	-0.00047	-0.00035	-0.00050	-0.00029	0	0	0	NS

c) The graphs on the following pages show nitrite nitrogen measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Nitrite (mg/L)
0.05
0.04
0.03
0.02
0.01
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 13: MAHURANGI HARBOUR – NITRATE NITROGEN

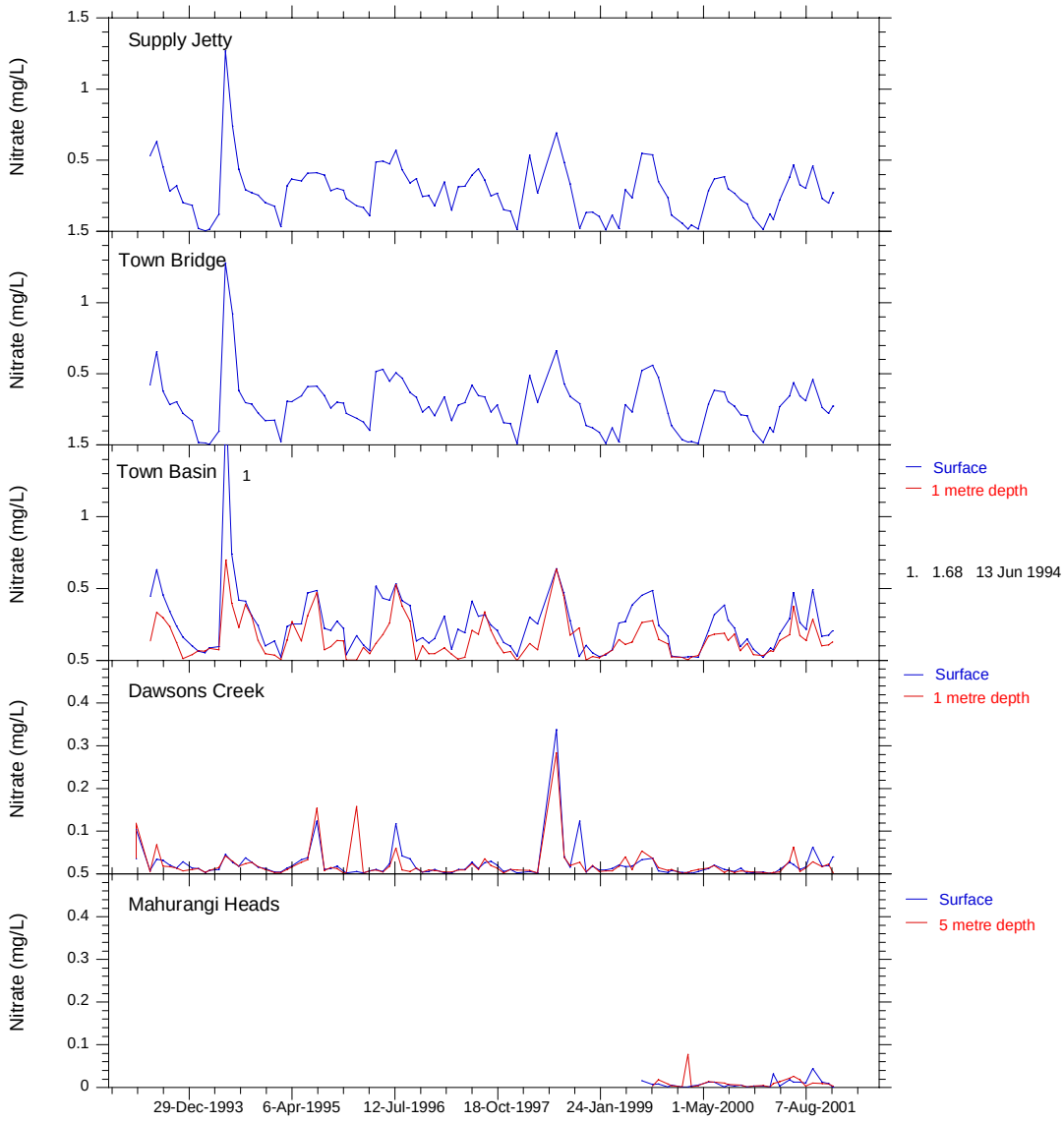
a) Nitrate nitrogen (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.010	0.016	0.020	0.032	0.003	0.001	0.001	0.003
26-Feb-01	0.109	0.117	0.084	0.063	0.000	0.000	0.000	0.000
12-Mar-01	0.075	0.084	0.072	0.055	0.000	0.001	0.030	0.007
10-Apr-01	0.216	0.262	0.180	0.133	0.005	0.000	0.000	0.008
25-May-01	0.373	0.336	0.286	0.172	0.024	0.027	0.013	0.018
12-Jun-01	0.463	0.432	0.468	0.365	0.016	0.057	0.004	0.018
10-Jul-01	0.319	0.337	0.256	0.168	0.008	0.004	0.009	0.015
07-Aug-01	0.300	0.302	0.212	0.135	0.014	0.012	0.008	0.001
06-Sep-01	0.455	0.454	0.487	0.282	0.059	0.027	0.042	0.008
18-Oct-01	0.226	0.256	0.166	0.099	0.016	0.015	0.011	0.007
16-Nov-01	0.195	0.220	0.170	0.103	0.018	0.021	0.007	0.006
05-Dec-01	0.269	0.268	0.203	0.122	0.038	0.002	0.000	0.001
Median	0.248	0.265	0.192	0.128	0.015	0.008	0.008	0.007
IQR/Median %	64	54	62	62	100	269	143	104

b) Statistical summary for 1993-2001: Nitrate nitrogen (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	98	98	98	98	99	99	29	28
Median	0.268	0.277	0.215	0.117	0.009	0.007	0.004	0.006
Normality	T	T	F	F	F	F	F	F
Seasonality	Y	Y	Y	Y	Y	Y	Y	Y
Trend	100%	95%	100%	90%	99%	98%	NS	NS
Slope	-0.0126	-0.0073	-0.0130	-0.0037	-0.00082	-0.00055	NS	NS

c) The graphs on the following pages show nitrate nitrogen measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Nitrate (mg/L)
1.5
1
0.5
0.4
0.3
0.2
0.1
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth
1. 1.68 13 Jun 1994

APPENDIX 14: MAHURANGI HARBOUR – DISSOLVED REACTIVE PHOSPHORUS

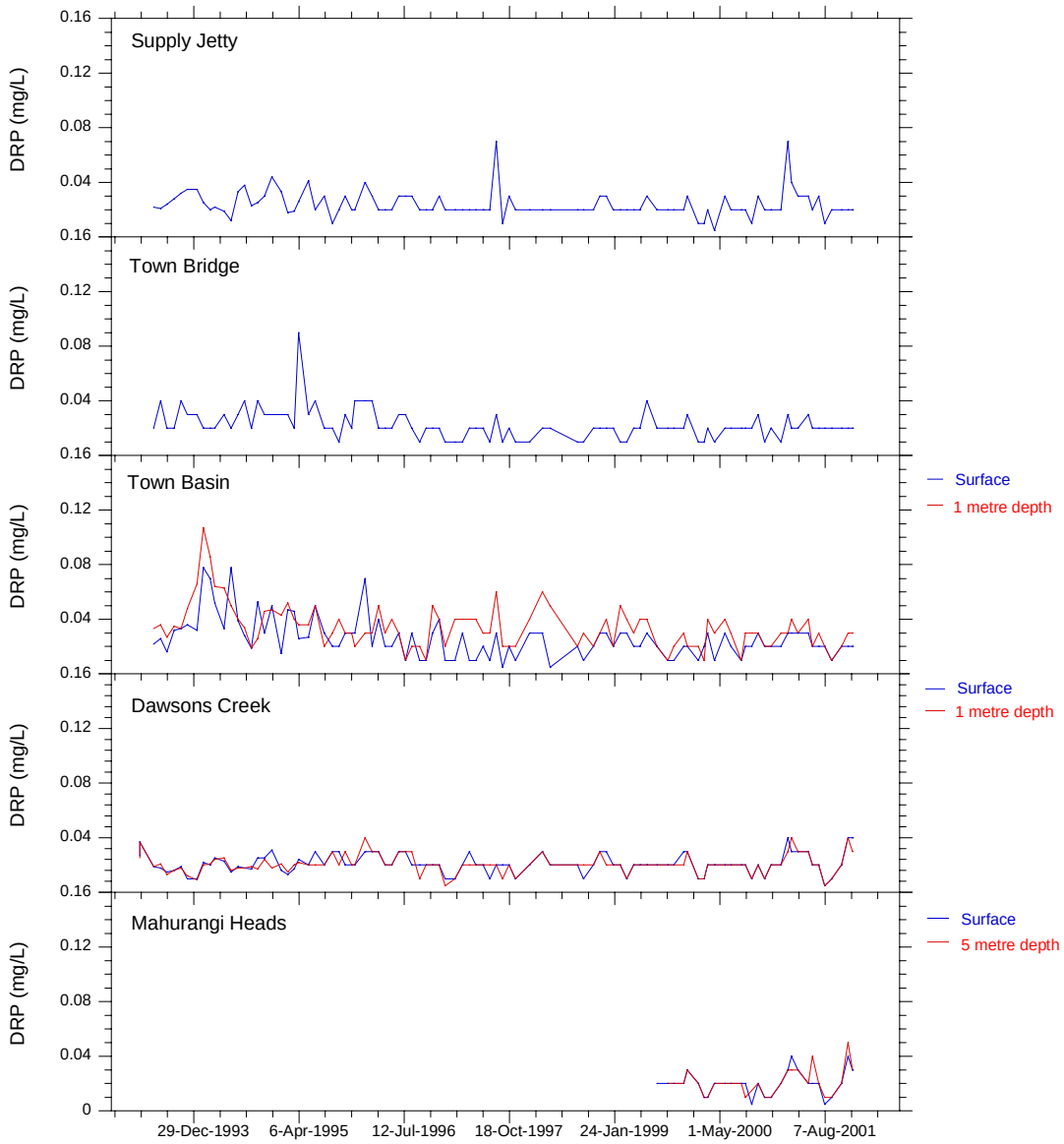
a) Dissolved reactive phosphorus (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02
26-Feb-01	0.07	0.03	0.03	0.03	0.04	0.03	0.03	0.03
12-Mar-01	0.04	0.02	0.03	0.04	0.03	0.04	0.04	0.03
10-Apr-01	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
25-May-01	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.02
12-Jun-01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04
10-Jul-01	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02
07-Aug-01	0.01	0.02	0.02	0.02	0.005	0.005	0.005	0.005
06-Sep-01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
18-Oct-01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
16-Nov-01	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.05
05-Dec-01	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.03
Median	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
IQR/Median %	50	0	50	33	50	40	40	40

b) Statistical summary for 1993-2001: Dissolved reactive phosphorus (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	96	96	96	9	97	97	29	96
Median	0.02	0.02	0.02	0.030	0.02	0.02	0.02	0.02
Normality	F	F	F	F	F	F	F	F
Seasonality	N	N	Y	Y	N	N	N	N
Trend	100%	99%	100%	100%	NS	NS	NS	100%
Slope	0	0	-0.002	-0.002	NS	NS	NS	0

c) The graphs on the following pages show dissolved reactive phosphorus measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
DRP (mg/L)
0.16
0.12
0.08
0.04
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 15: MAHURANGI HARBOUR – TOTAL PHOSPHORUS

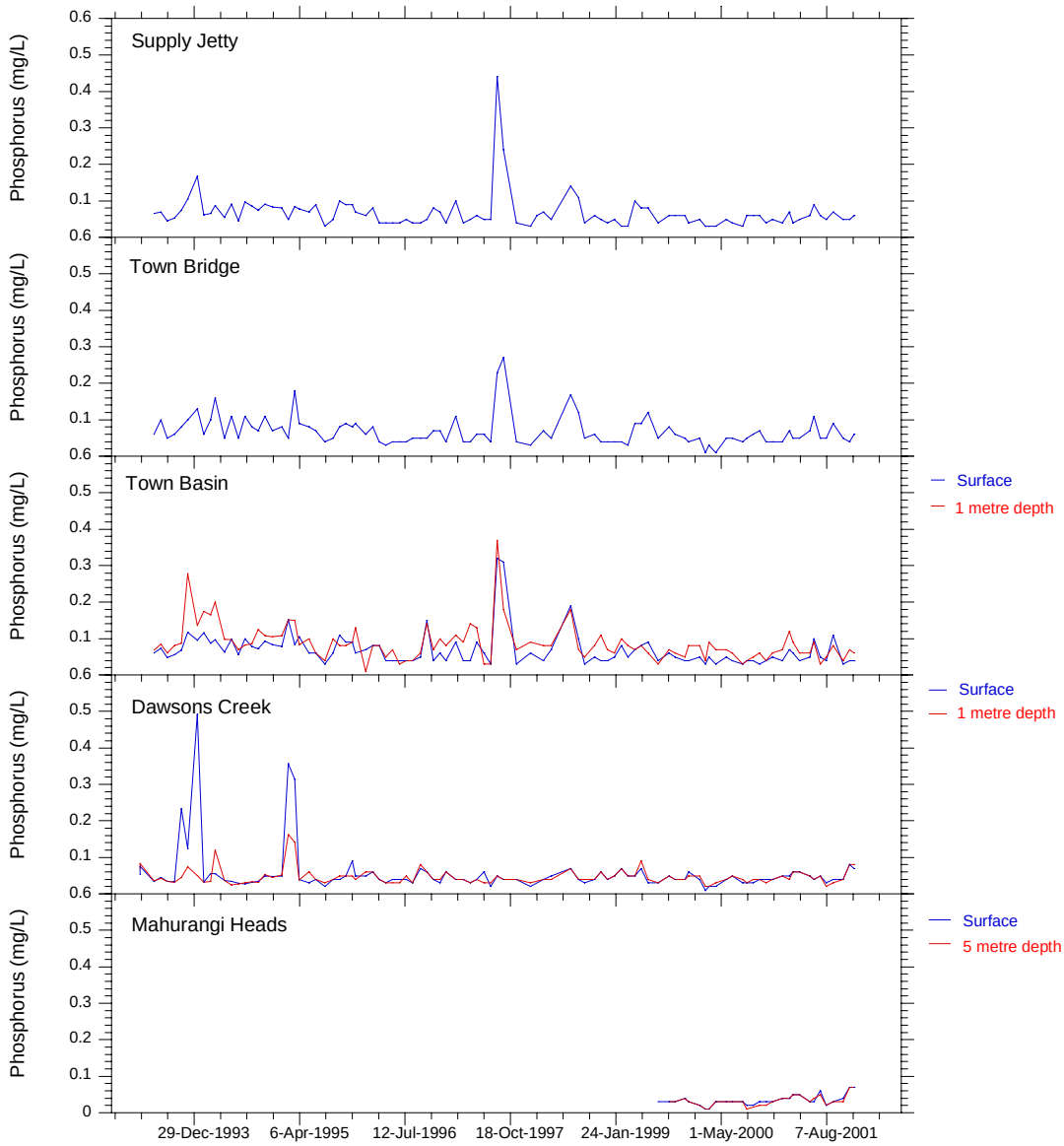
a) Total phosphorus (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.04	0.04	0.04	0.07	0.05	0.05	0.04	0.04
26-Feb-01	0.07	0.07	0.07	0.12	0.05	0.04	0.04	0.04
12-Mar-01	0.04	0.05	0.06	0.09	0.06	0.06	0.05	0.05
10-Apr-01	0.05	0.05	0.04	0.06	0.06	0.06	0.05	0.05
25-May-01	0.06	0.07	0.05	0.06	0.05	0.05	0.03	0.06
12-Jun-01	0.09	0.11	0.10	0.09	0.04	0.04	0.03	0.04
10-Jul-01	0.06	0.05	0.05	0.03	0.05	0.05	0.06	0.05
07-Aug-01	0.05	0.05	0.04	0.05	0.03	0.02	0.02	0.02
06-Sep-01	0.07	0.09	0.11	0.08	0.04	0.03	0.03	0.03
18-Oct-01	0.05	0.05	0.03	0.04	0.04	0.04	0.04	0.03
16-Nov-01	0.05	0.04	0.04	0.07	0.08	0.08	0.07	0.07
05-Dec-01	0.06	0.06	0.04	0.06	0.07	0.08	0.07	0.07
Median	0.06	0.05	0.05	0.07	0.05	0.05	0.04	0.05
IQR/Median %	23	40	50	38	40	40	56	33

b) Statistical summary for 1993-2001: Total phosphorus (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	96	96	96	97	97	29	28
Median	0.06	0.06	0.06	0.08	0.04	0.04	0.03	0.03
Normality	F	F	F	F	F	F	F	F
Seasonality	N	N	N	Y	Y	Y	N	N
Trend	100%	100%	100%	100%	NS	NS	92%	NS
Slope	-0.003	-0.004	-0.005	-0.006	NS	NS	0.005	NS

c) The graphs on the following pages show total phosphorus measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Phosphorus (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 16: MAHURANGI HARBOUR – CHLOROPHYLL *a*

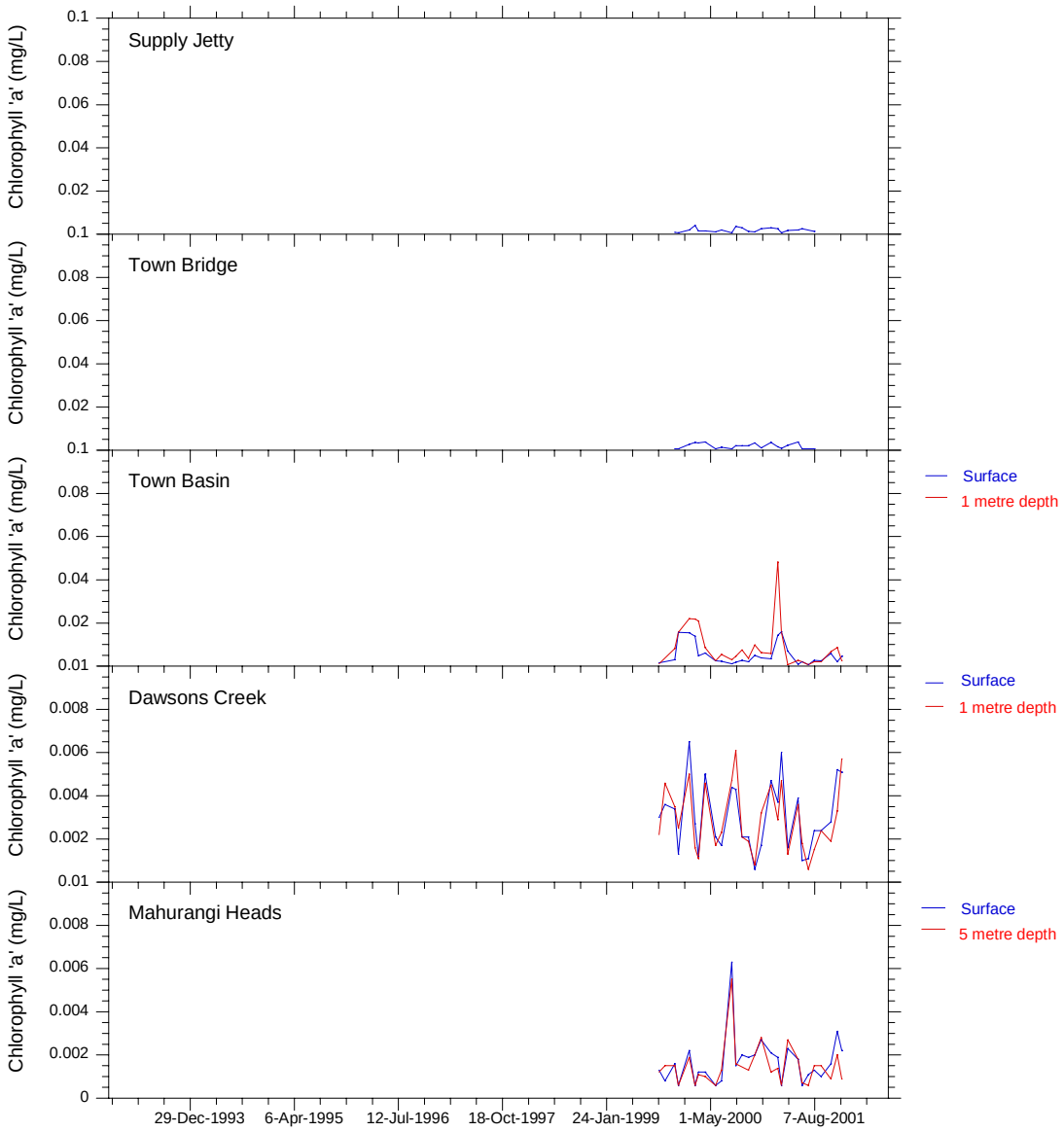
a) Chlorophyll *a* (mg/L) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	0.0030	0.0036	0.0034	0.0059	0.0047	0.0045	0.0021	0.0012
26-Feb-01	0.0024	0.0016	0.0143	0.0482	0.0037	0.0029	0.0019	0.0014
12-Mar-01	0.0007	0.0010	0.0160	0.0160	0.0060	0.0047	0.0006	0.0003
10-Apr-01	0.0180	0.0023	0.0070	0.0007	0.0016	0.0013	0.0023	0.0027
25-May-01	0.0020	0.0039	0.0010	0.0027	0.0039	0.0036	0.0018	0.0018
12-Jun-01	0.0024	0.0003	0.0022	0.0020	0.0010	0.0018	0.0003	0.0007
10-Jul-01			0.0008	0.0003	0.0010	0.0003	0.0011	0.0003
07-Aug-01	0.0014	0.0003	0.0028	0.0022	0.0024	0.0015	0.0013	0.0015
06-Sep-01			0.0025	0.0020	0.0024	0.0024	0.0010	0.0015
18-Oct-01			0.0060	0.0068	0.0028	0.0019	0.0016	0.0009
16-Nov-01			0.0021	0.0086	0.0052	0.0033	0.0031	0.0020
05-Dec-01			0.0045	0.0026	0.0051	0.0057	0.0022	0.0009
Median	0.0024	0.0016	0.0031	0.0027	0.0033	0.0027	0.0017	0.0013
IQR/Median %	42	144	131	198	80	79	62	56

b) Statistical summary for 1993-2001: Chlorophyll *a* (mg/L)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	21	21	27	27	28	28	28	28
Median	0.0018	0.0020	0.0029	0.0059	0.0028	0.0025	0.0016	0.0013
Normality	T	T	F	F	T	T	F	F
Seasonality	N	N	Y	Y	N	N	Y	N
Trend	81%	NS	NS	NS	NS	NS	90	NS
Slope	0.0006	NS	NS	NS	NS	NS	0.0004	NS

c) The graphs on the following pages show chlorophyll *a* measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Chlorophyll 'a' (mg/L)
0.1
0.08
0.06
0.04
0.02
0.01
0.008
0.006
0.004
0.002
0
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001
Surface
1 metre depth
Surface
1 metre depth
Surface
5 metre depth

APPENDIX 17: MAHURANGI HARBOUR – PRESUMPTIVE COLIFORM

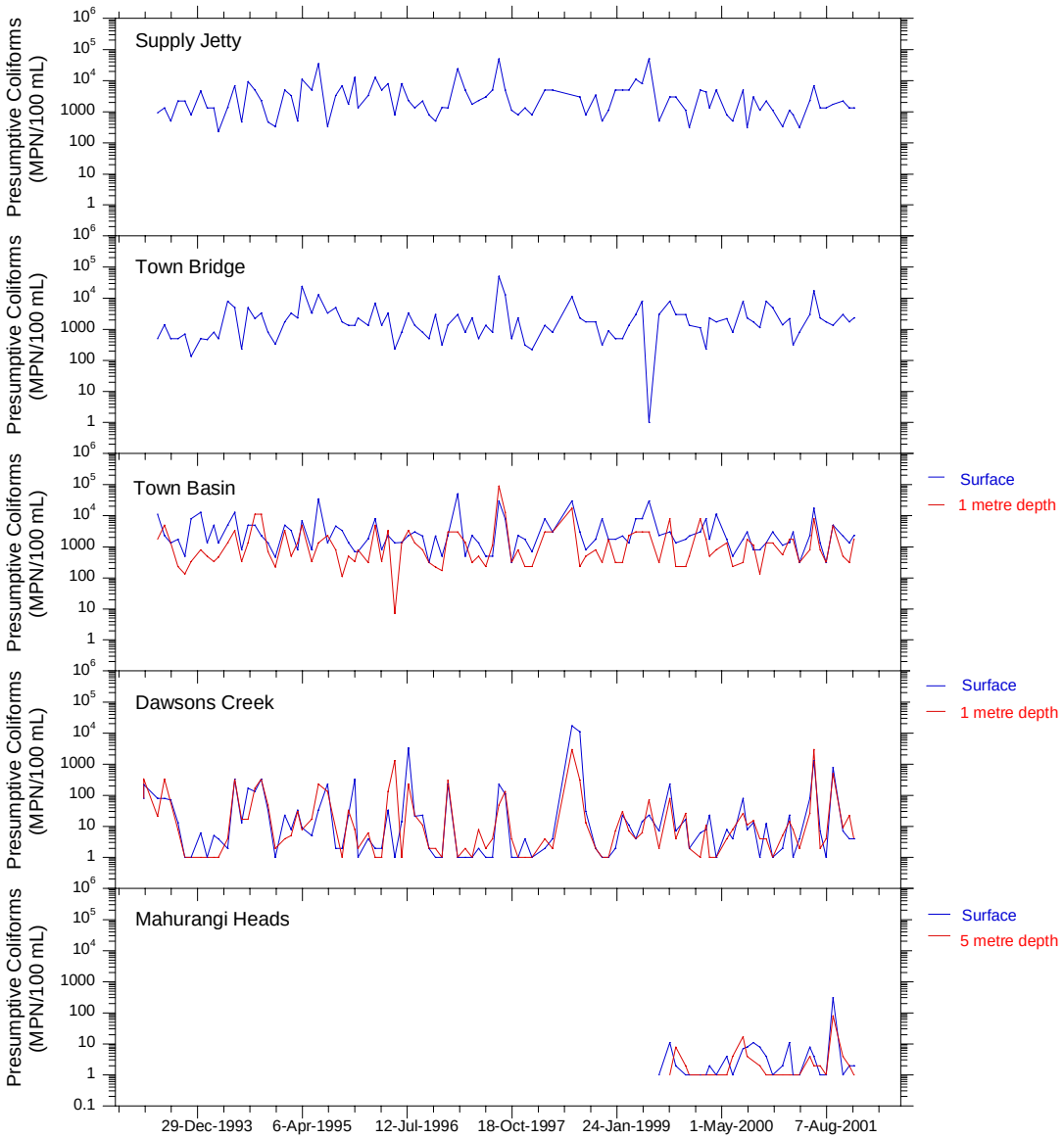
a) Presumptive coliforms (MPN/100 mL) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	330	1400	1100	540	2	5	2	1
26-Feb-01	1100	2200	1400	1700	23	14	11	1
12-Mar-01	800	300	3000	1700	1	8	1	1
10-Apr-01	300	800	300	300	4	2	1	1
25-May-01	2300	3000	2300	800	80	26	8	4
12-Jun-01	7000	17000	17000	8000	1300	3000	4	2
10-Jul-01	1300	2300	1300	800	7	2	1	2
07-Aug-01	1300	1700	300	300	1	4	1	1
06-Sep-01	1700	1300	5000	5000	800	500	300	80
18-Oct-01	2200	3000	2200	500	7	9	1	4
16-Nov-01	1300	1700	1300	300	4	22	2	2
05-Dec-01	1300	2300	2300	1700	4	4	2	1
Median	1300	1950	1800	800	6	9	2	2
IQR/Median %	62	56	68	156	614	224	200	100

b) Statistical summary for 1993-2001: Presumptive coliforms (MPN/100 mL)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	97	98	98	98	99	97	29	28
Median	2200	1700	2200	800	7	6	2	1
Normality	F	F	F	F	F	F	F	F
Seasonality	N	N	N	N	Y	Y	N	Y
Trend	NS	NS	NS	NS	NS	NS	NS	NS
Slope	NS	NS	NS	NS	NS	NS	NS	NS

c) The graphs on the following pages show presumptive coliform measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Presumptive Coliforms (MPN/100 mL)
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 18: MAHURANGI HARBOUR – FAECAL COLIFORM

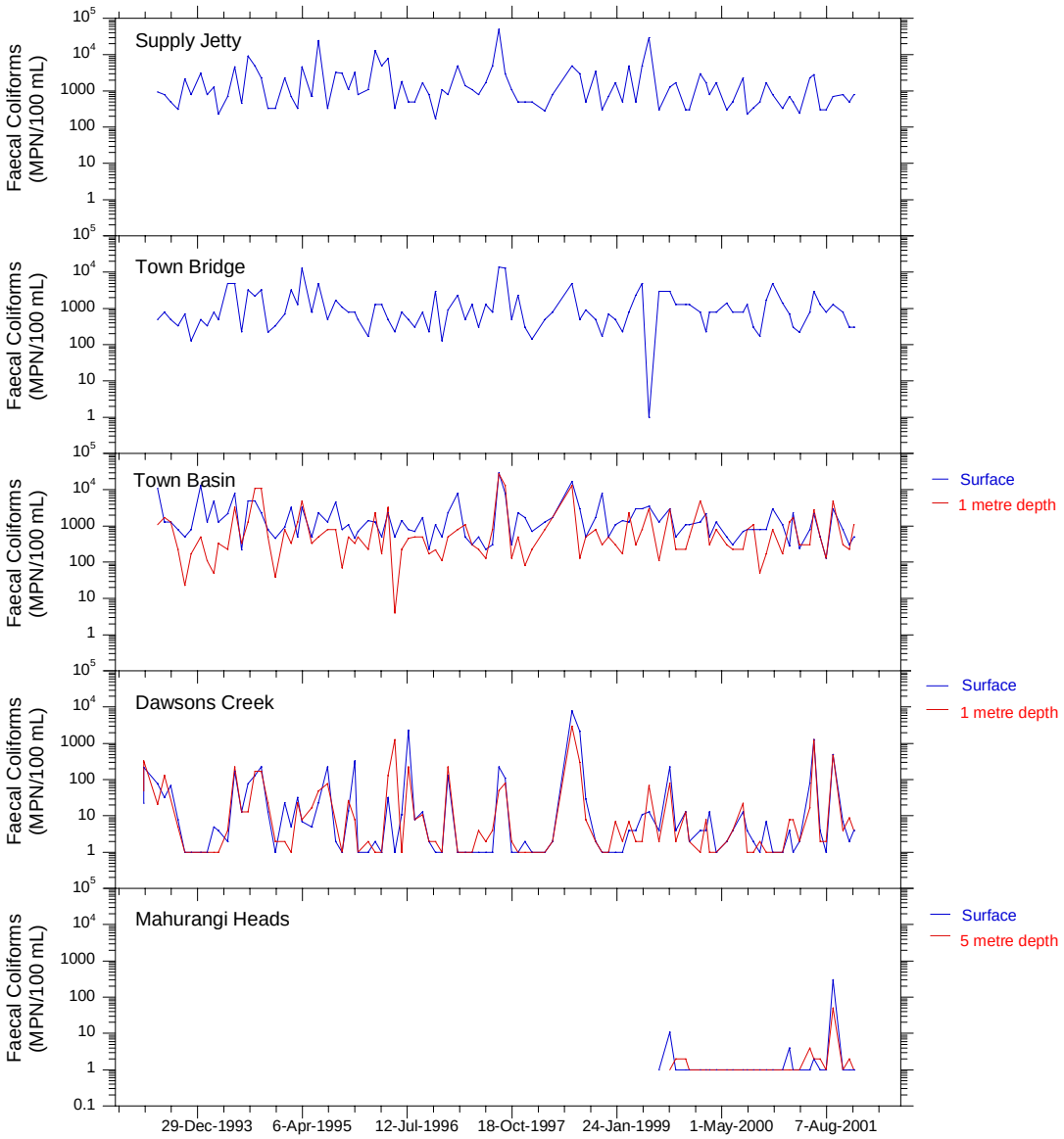
a) Faecal coliforms (MPN/100 mL) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	330	1400	1100	170	1	1	1	1
26-Feb-01	700	700	280	1300	4	8	4	1
12-Mar-01	500	300	2300	1700	1	8	1	1
10-Apr-01	240	220	240	300	2	2	1	1
25-May-01	2300	800	800	300	80	17	1	4
12-Jun-01	2800	3000	2200	2800	1300	1300	2	2
10-Jul-01	300	1300	500	500	4	2	1	2
07-Aug-01	300	800	130	130	1	2	1	2
06-Sep-01	700	1300	3000	5000	500	500	300	50
18-Oct-01	800	800	800	300	7	4	1	1
16-Nov-01	500	300	300	230	2	9	1	2
05-Dec-01	800	300	500	1100	4	4	1	1
Median	600	800	650	400	4	6	1	2
IQR/Median %	80	125	166	279	588	150	25	67

b) Statistical summary for 1993-2001: Faecal coliforms (MPN/100 mL)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	98	98	98	98	99	97	29	28
Median	800	800	1100	490	4	2	1	1
Normality	F	F	F	F	F	F	F	F
Seasonality	N	N	N	N	Y	Y	N	N
Trend	90%	NS	NS	NS	NS	NS	NS	NS
Slope	-53.8	NS	NS	NS	NS	NS	NS	NS

c) The graphs on the following pages show faecal coliform measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Faecal Coliforms (MPN/100 mL)
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 19: MAHURANGI HARBOUR – ENTEROCOCCI

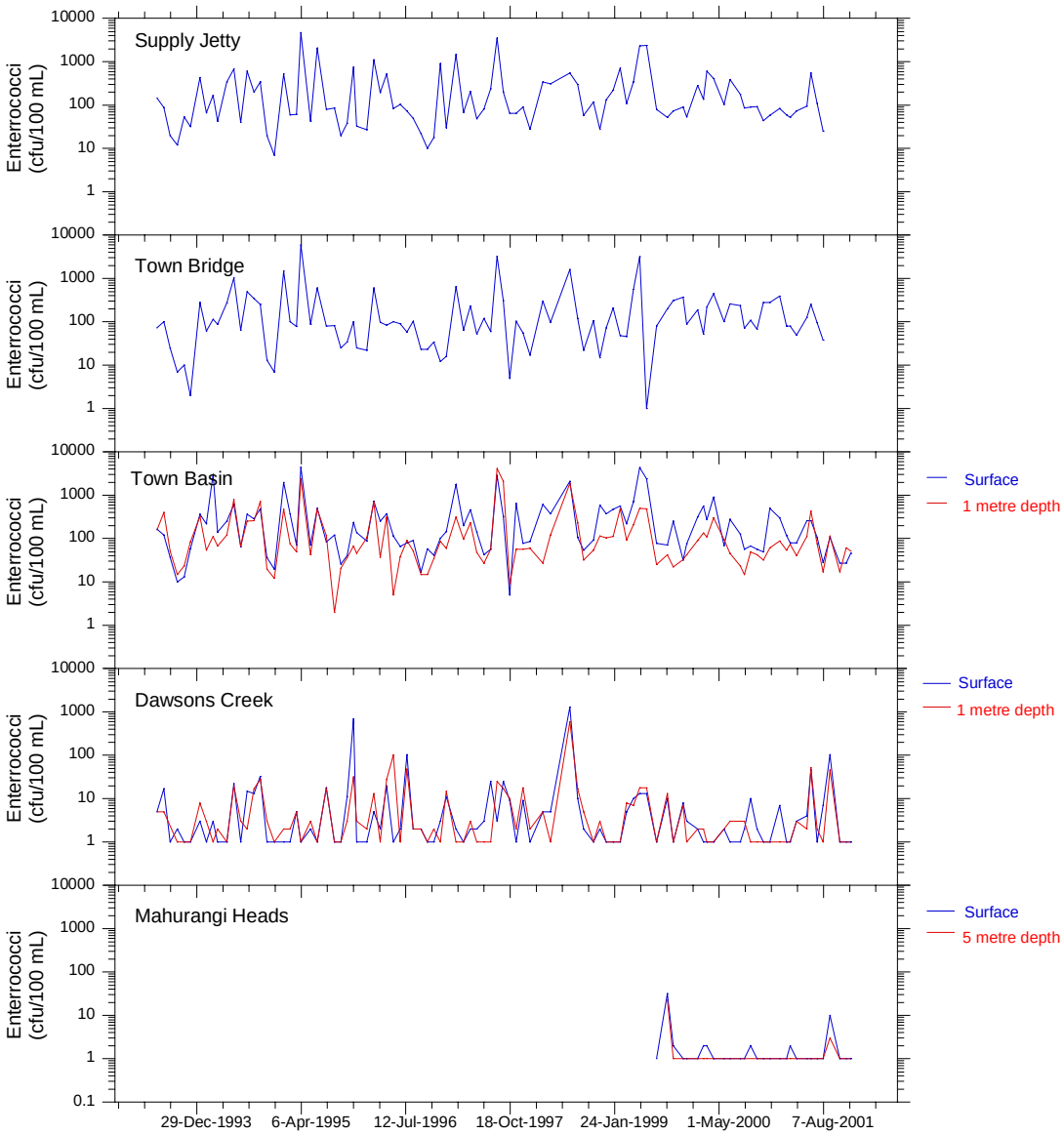
a) Enterococci (cfu/100 mL) during January 2001 - December 2001

Date	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
25-Jan-01	84	390	300	88	7	1	1	1
26-Feb-01	60	80	118	54	1	1	1	1
12-Mar-01	52	80	80	74	1	1	2	1
10-Apr-01	74	50	80	40	3	3	1	1
25-May-01	96	128	260	110	4	2	1	1
12-Jun-01	550	250	260	430	46	52	1	1
10-Jul-01	108	96	106	76	1	2	1	1
07-Aug-01	25	38	28	17	7	1	1	1
06-Sep-01			106	114	104	46	10	3
18-Oct-01			27	17	1	1	1	1
16-Nov-01			27	62	1	1	1	1
05-Dec-01			46	52	1	1	1	1
Median	79	88	93	68	2	1	1	1
IQR/Median %	52	98	120	65	300	125	0	0

b) Statistical summary for 1993-2001: Enterococci (cfu/100 mL)

	Supply Intake Jetty	Town Bridge	Town Basin surface	Town Basin 1 m	Dawsons Creek surface	Dawsons Creek 1 m	Mahurangi Heads surface	Mahurangi Heads 5 m
N	94	94	98	98	98	97	29	28
Median	90	93	125	68	2	2	1	1
Normality	F	F	F	F	F	F	F	F
Seasonality	Y	N	Y	Y	Y	N	Y	N
Trend	NS	NS	NS	NS	NS	NS	NS	NS
Slope	NS	NS	NS	NS	NS	NS	NS	NS

c) The graphs on the following pages show enterococci measurements from January 1993 to December 2001 (where data available).


Supply Jetty
Town Bridge
Town Basin
Dawsons Creek
Mahurangi Heads
Enterrococci (cfu/100 mL)
10000
1000
100
10
1
0.1
Surface
1 metre depth
5 metre depth
29-Dec-1993
6-Apr-1995
12-Jul-1996
18-Oct-1997
24-Jan-1999
1-May-2000
7-Aug-2001

APPENDIX 20: TAMAKI ESTUARY – TEMPERATURE

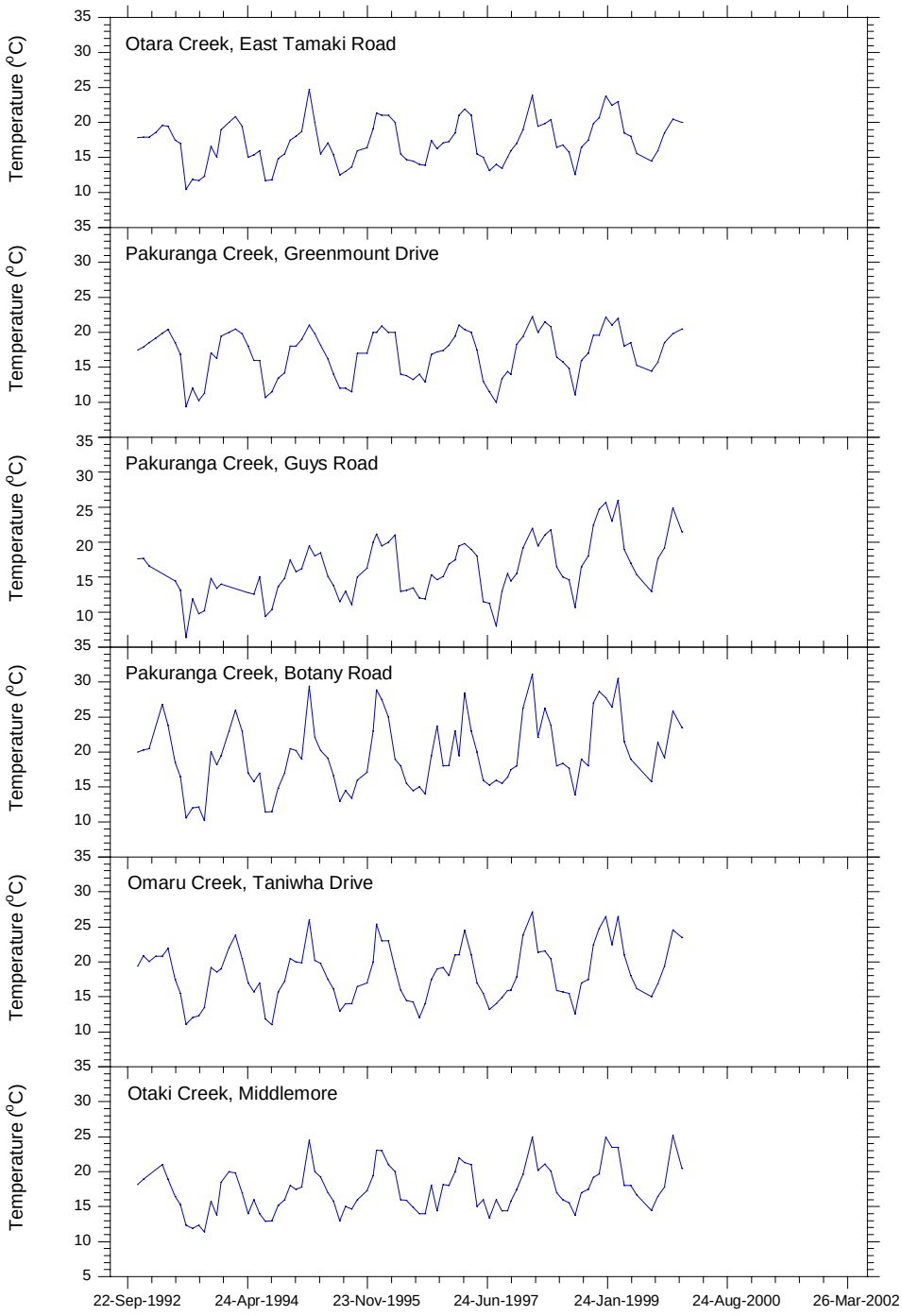
a) Temperature (^{o}C) during January 2001 - December 2001

Date	Otara Creek East Tamaki	Pakuranga Ck Greenmount	Pakuranga Ck Guys	Pakuranga Ck Botany	Omaru Creek Taniwha	Otaki Creek Middlemore	No. 7 Buoy surface	Panmure Bridge	Otara Lake weir
22-Jan-01									
20-Feb-01				Temperature data currently unavailable for 2001					
23-Mar-01									
23-Apr-01									
22-May-01									
22-Jun-01									
20-Jul-01									
17-Aug-01									
17-Sep-01									
15-Oct-01									
13-Nov-01									
13-Dec-01									
Median									
IQR/Median %									

b) Statistical summary for 1992-2001: Temperature (^{o}C)

	Otara Creek East Tamaki	Pakuranga Ck Greenmount	Pakuranga Ck Guys	Pakuranga Ck Botany	Omaru Creek Taniwha	Otaki Creek Middlemore	No. 7 Buoy surface	Panmure Basin	Panmure Bridge	Otara Lake weir
N	88	88	82	87	88	86	70	81	6	57
Median	17.1	17.5	15.5	19.0	18.0	17.2	17.7	18.0	20.7	18.00
Normality	T	F	T	T	T	T	T	T	INS.	T
Seasonality	Y	Y	Y	Y	Y	Y	Y	Y	INS.	Y
Trend	100%	100%	100%	100%	100%	100%	99%	96%	INS.	NS
Slope	0.43	0.33	0.88	0.80	0.45	0.48	0.38	0.30	INS.	NS

c) The graphs on the following pages show temperature measurements from January 1992 to December 2001 (where data available).


Otara Creek, East Tamaki Road
Pakuranga Creek, Greenmount Drive
Pakuranga Creek, Guys Road
Pakuranga Creek, Botany Road
Omaru Creek, Taniwha Drive
Otaki Creek, Middlemore
Temperature (°C)
35
30
25
20
15
10
5
22-Sep-1992
24-Apr-1994
23-Nov-1995
24-Jun-1997
24-Jan-1999
24-Aug-2000
26-Mar-2002