Waitakere City Council
Te Taiao o Waitakere

PROJECT TWIN STREAMS WAITAKERE

Project Twin Streams
Catchment Monitoring

WATER QUALITY MONITORING REPORT
2005 - 2006

Kingett Mitchell Ltd
RESOURCE & ENVIRONMENTAL CONSULTANTS
• Enviro Ventures Ltd • Diffuse Sources Ltd

Project Twin Streams
Water Quality Monitoring
Summer 2005–2006

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Executive Summary

This report documents the water quality monitoring component of the Project Twin Streams Pressure-State-Response (PSR) monitoring programme, conducted over the summer of 2005–2006.

The report:

- documents water quality data acquired between December 2005 and May 2006
- provides a statistical summary of the data as a basis for comparison with previous and future monitoring data
- gives an overview of water quality conditions over the summer of 2005–2006, including comparison with guidelines for aquatic health and human recreation
- examines changes in water quality in the Twin Streams catchment between the headwaters and lower reaches of each major stream branch (Oratia, Opanuku, Swanson, and Waikumete streams), and
- compares water quality in summer 2005–6 with that in 2003–4.

Monitoring

Monitoring was conducted approximately monthly (weather permitting) between December 2005 and May 2006 at the same 15 sites in the Oratia, Opanuku, and Waikumete Streams as those used in summer 2003–4. In addition, four new stream sites in the Swanson Stream were also sampled.

Samples were analysed for key urban water quality indicators – E. coli, ammonia, dissolved phosphorus, nitrate, nitrite, dissolved copper and dissolved zinc.

Water temperature was continuously monitored between February and May 2006 at most sites.

Key findings

Spatial patterns in water quality were similar to those recorded in the last monitoring conducted in summer 2003–4.

Overall, the Opanuku and Oratia streams generally have higher water quality than the Waikumete Stream system. This is evident in lower levels of dissolved Zn, nitrate (and oxidised nitrogen), nitrite, and ammonia in the Oratia and Opanuku streams. The Oratia Stream headwaters did, however, have elevated dissolved phosphorus levels.

The Swanson Stream has lower concentrations of Zn than the other streams, but Cu and E. coli levels were comparable with the Opanuku and Oratia Streams. The Swanson Stream did, however, show marked nitrate enrichment, and slightly elevated nitrite levels, at rural and urban sites.

Ecological effects are likely to be subtle and limited mainly to the urban stream sites, where concentrations of dissolved Cu and Zn approach and sometimes exceed levels indicative of toxicity.

Bacterial water quality is generally poor, and probably unsuitable for human contact recreation at all sites below the bush headwaters, with the Whakarino and Waikumete being particularly poor. Both rural and urban sources of contamination contribute to this problem.

Comparison of the summer 2005–6 monitoring data with that collected in 2003–4 showed reasonably consistent spatial patterns in water quality. Some differences were noted, mainly in nutrient and metals' concentrations in the Waikumete Stream system. These concentrations were generally higher in 2005–6 than in 2003–4. Higher flows in the last sampling in May 2006 were probably contributors to this effect.

Recommendations for future water quality monitoring

All the sites monitored gave useful information. It is important to continue to monitor them all. Effort should continue to be made to ensure base flow conditions are sampled each month to reduce data variability and improve comparability over time.

The next round of monitoring should be undertaken in summer 2008–9, beginning in November 2008 and ending in April 2009. Catchment pressure data for the period 2003–2009 will be required in order to interpret the water (and sediment) quality data collected in the programme.

Contents

1 Introduction

As part of Project Twin Streams (PTS), Waitakere City Council has established a Pressure-State-Response (PSR) environmental monitoring programme that aims to improve the Council's understanding of the links between catchment activities and the quality of the streams and downstream estuary receiving environments.

The monitoring programme, described in EVA et al. (2003a–c), comprises:

- *pressure* monitoring, including land use, potential sources of contamination, and treatment;
- *aquatic ecology* and *habitat quality* assessment;
- *stream water quality* monitoring;
- *stream sediment quality* monitoring; and
- *estuarine sediment quality* monitoring.

The combined results of this monitoring will, over time, enable changes in the quality of the aquatic environment in the Twin Streams catchment resulting from changes in catchment land use to be measured, and the effectiveness of Council's management of land use pressures to be assessed.

This report documents the stream water quality monitoring component of this programme, conducted in the Twin Streams catchment in summer 2005–6.

It represents the second set of monitoring – the first was undertaken in summer 2003–2004, as reported by EVA et al. (2004).

The report:

- documents water quality data acquired between December 2005 and May 2006;
- provides a statistical summary of the data as a basis for comparison with past and future monitoring data;
- gives an overview of water quality conditions over the summer of 2005–2006, including comparison with guidelines for aquatic health and human recreation;
- examines changes in water quality in the Twin Streams catchment between the headwaters and lower reaches of each major stream branch (Oratia, Opanuku, and Waikumete streams), and
- provides a brief comparison with water quality in summer 2003–4.

Based on the results of this monitoring, recommendations for future monitoring in the PTS programme are made.

2 Sampling and analysis

Sampling was conducted by Diffuse Sources (December 2005) and Kingett Mitchell & Associates (January–May 2006).

2.1 Sampling sites

Site locations and descriptions were the same as those monitored in 2003–4 (EVA et al. 2004), as summarised in Table 2.1 and Figure 2.1a & b. In addition, four new sites on the Swanson Stream were added for summer 2005-6 – locations are given in Table 2.2 and Figure 2.2.

These 19 sites were sampled on 14/15th December 2005, 31st January 2006, 22nd February 2006, 31st March 2006, and 12th May 2006, giving 5 sets of water quality data per site.

2.2 Sampling conditions

Sampling was aimed at being undertaken in dry weather, at least 2 days after significant rainfall. However, mixed weather was encountered during April, and therefore sampling was delayed until early-mid May.

Sampling was initiated in December (compared with November in the 2003-4 monitoring) and therefore the monitoring period is approximately one month later than was carried out in 2003–4 (which was monthly between November and April inclusive), and one fewer sets of samples was collected (5 for 2005–6, compared with 6 for 2003–4).

Stream flow on the sampling dates, taken from the ARC flow recording stations[1], are listed in Table 2.3 and shown in Figure 2.3. These flow data indicate that sampling occurred at, or near, base flows on all occasions except for the May 2006 sampling, when streams flows were much higher. These samples were taken soon after a storm event and so represent storm recession conditions rather than base flow.

[1] The Oratia Stream flow-monitoring site is downstream of site H and the confluence with the Waikumete Stream, on Millbrook Rd approx 200m upstream of the View Rd bridge. Grid Ref NZMS260 R11:559779. The Opanuku Stream site is located in Vintage Reserve off Kaheel Lane off Vintage Rd, between sites C and I. Grid Ref NZMS260 R11:551790. The Swanson Stream site is at Woodside Reserve, adjacent to the S water quality sampling site.

Table 2.1 Water quality sampling sites in the Oratia, Opanuku, and Waikumete Streams

Site Code	Stream Access Point	Catchment	SMU	Land use	Purpose	Grid Reference (NZMS 260 R11)
A	Stoney Creek Sharp Track	Opanuku	16	Native bush	Headwaters reference site	265032 647623
B	Opanuku Stream Candia Road	Opanuku	16	Mixed rural	Mixed rural	265256 647729
C	Opanuku Stream Border Road	Opanuku	15	Peri-urban to urban boundary	Land use change	265434 647771
D	Opanuku Stream Sel Peacocke Drive	Opanuku	15	Intensive urban	Lower catchment cumulative effects	265592 647927
E	Potters Stream Bendalls Lane	Oratia	13	Native bush	Headwaters reference site	265214 647408
F	Oratia Stream West Coast Road	Oratia	13	Rural	Intensive peri-urban	265367 647462
G	Oratia Stream Parrs Cross Road	Oratia	13/10 boundary (SMU 10 d/s)	Peri-urban to urban boundary	Land use change	265518 647615
H	Oratia Stream Aetna Place	Oratia	10	Industrial & mixed pastoral	Land use change (to urban)	265564 647695
I	Oratia Stream Westfield carpark	Oratia	10	Intensive urban	Lower catchment cumulative effects	265607 647874
J	Hibernia Stream Waerenga Place	Waikumete	12	Bush residential	Bush living reference	265763 647284
K	Hibernia Stream Ceramco Park	Waikumete	12	Bush residential	Bush residential	265761 647425
L	Whakarino Stream Withers Reserve	Waikumete	12	(Bush) residential	Bush residential + WWOFs	265696 647415
M	Waikumete Stream Glendale Road	Waikumete	11	Residential	Residential + WWOFs Confluence of tributaries	265739 647454
N	Waikumete Stream West Coast Road	Waikumete	11	Residential & reserve	Urban living	265685 647571
O	Waikumete Stream Benita Place	Waikumete	10	Light industrial & residential	Lower catchment cumulative effect	265595 647663

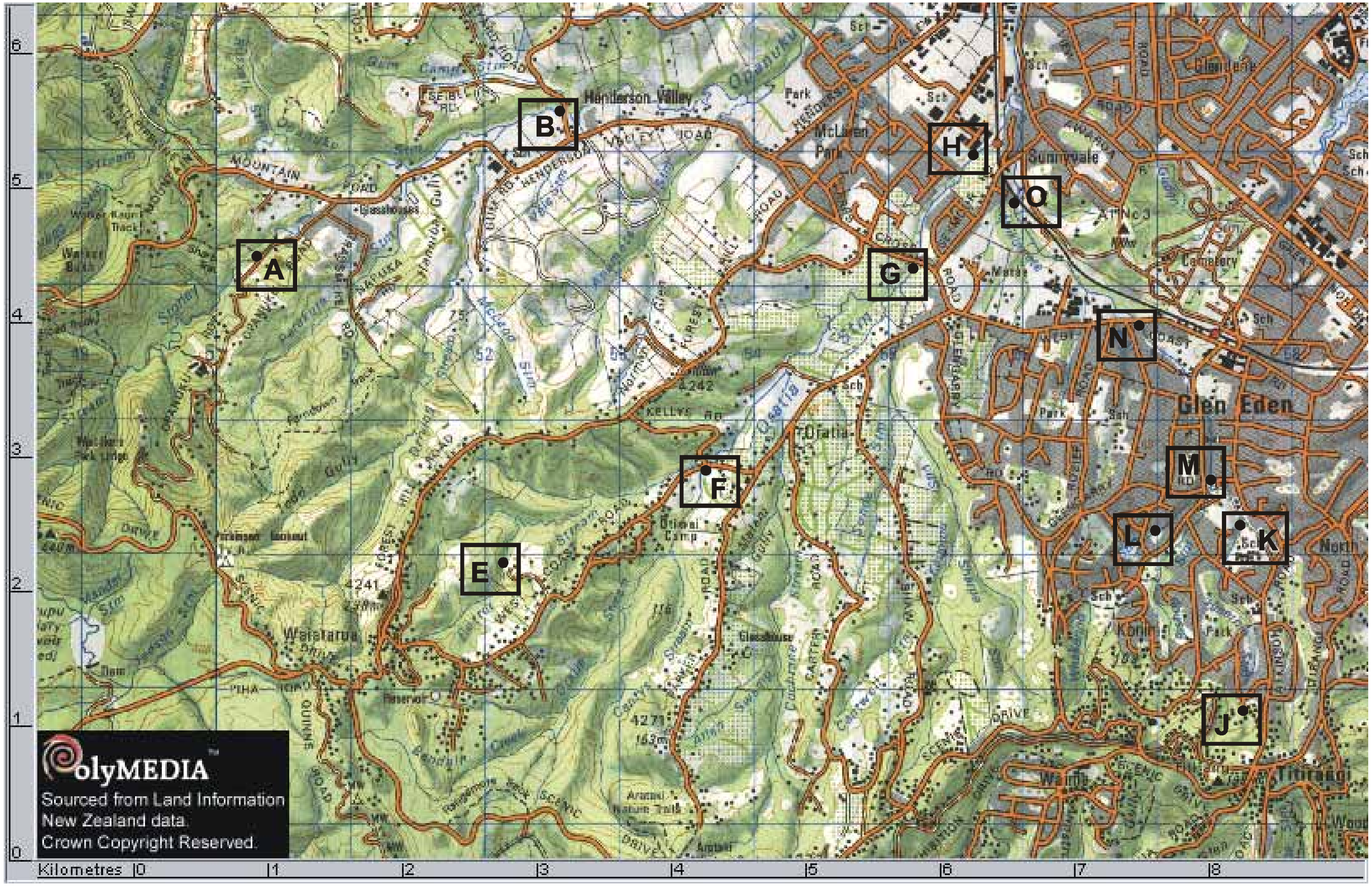


Figure 2.1a Sampling sites in the Oratia, Opanuku, and Waikumete Streams

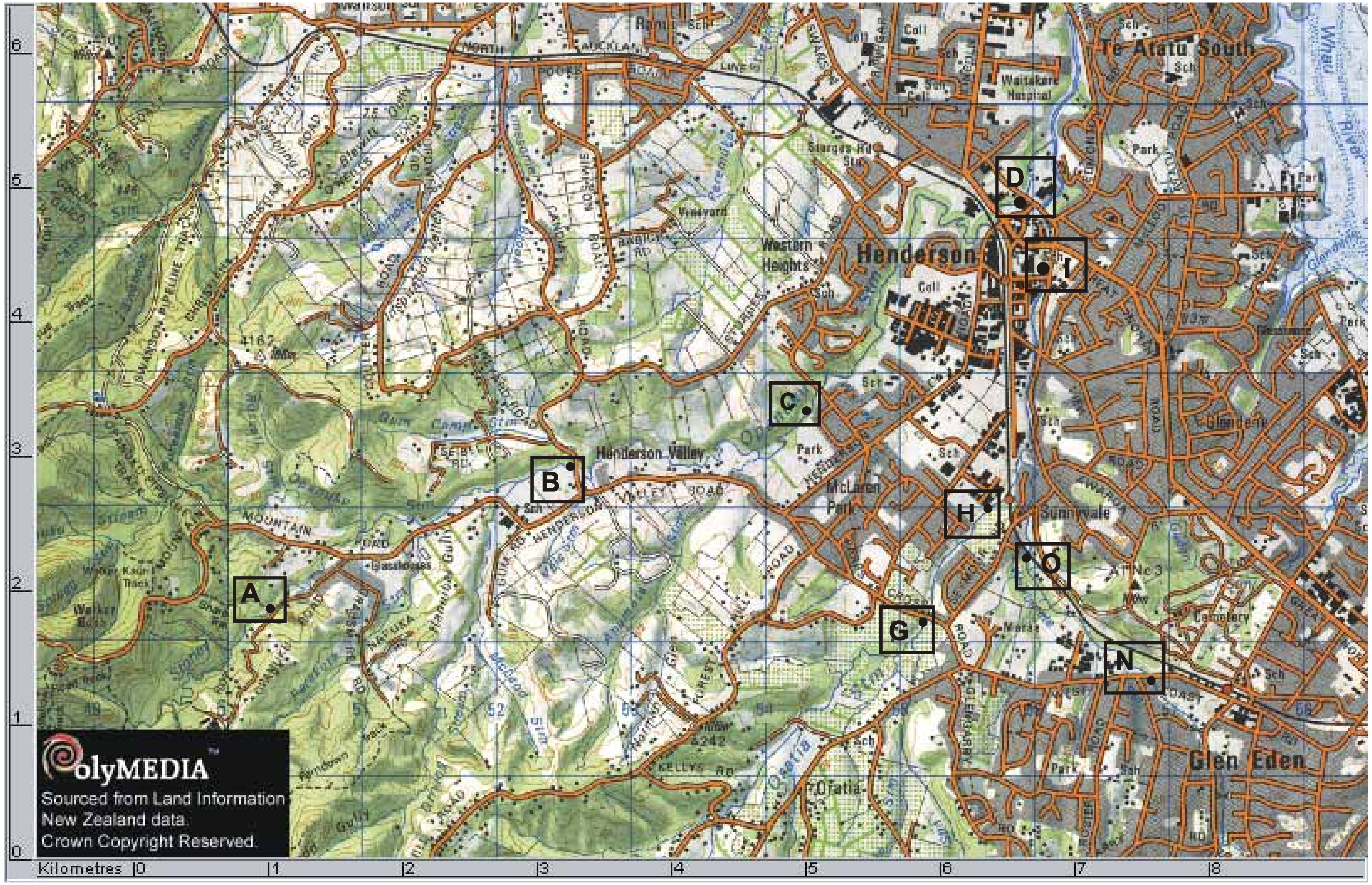


Figure 2.1b Sampling sites in the Oratia, Opanuku, and Waikumete Streams

Table 2.2 Sampling sites on the Swanson Stream

Site Code	Access Point	Upstream land use	GPS Reference
P	Tram Valley Rd	Native bush	E 2649676 N 6479356
Q	Parklands Ave	Rural	E 2650475 N 6480931
R	u/s Birdwood Rd bridge	Urban/rural	E 2652554 N 6481171
S	Woodside Reserve	Urban	E 2654226 N 6481622

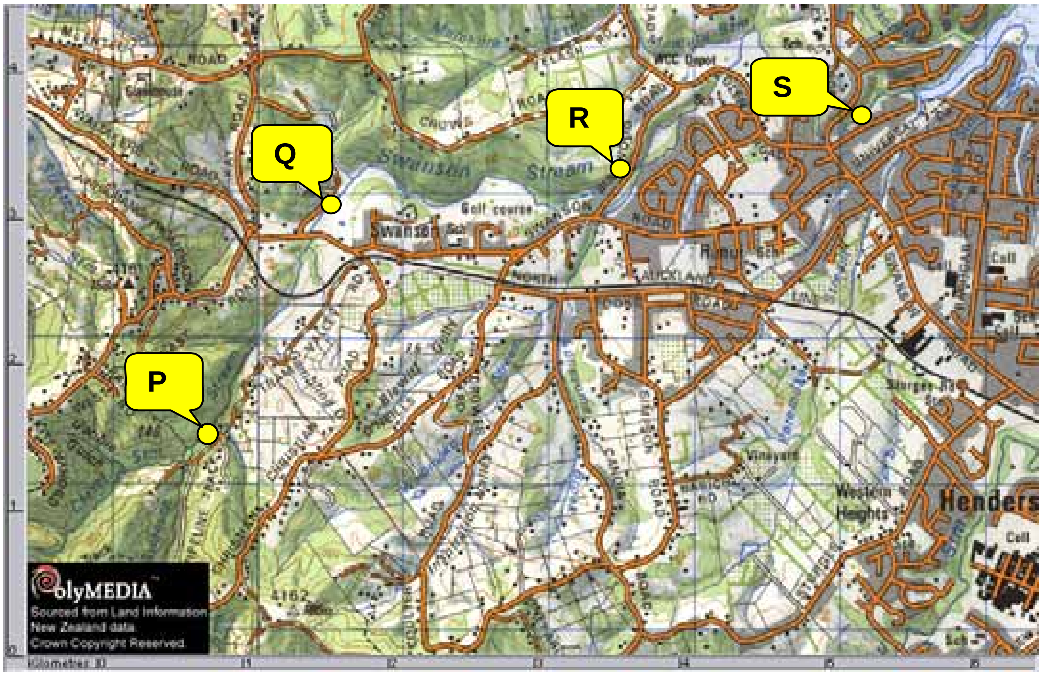


Figure 2.2 Sampling sites on the Swanson Stream

Table 2.2 Average daytime stream flows on the day of water quality sampling (taken from the ARC flow records)

Sampling Occasion		Flow (m^3/s)		
Month	Date	Opanuku	Oratia	Swanson
December	14/12/05	–	–	0.105
	15/12/05	0.095	0.096	–
January	31/01/06	0.134	0.120	0.136
February	22/02/06	0.080	0.057	0.025
March	31/03/04	0.207	0.088	0.107
May	12/05/06	3.02	2.80	2.64

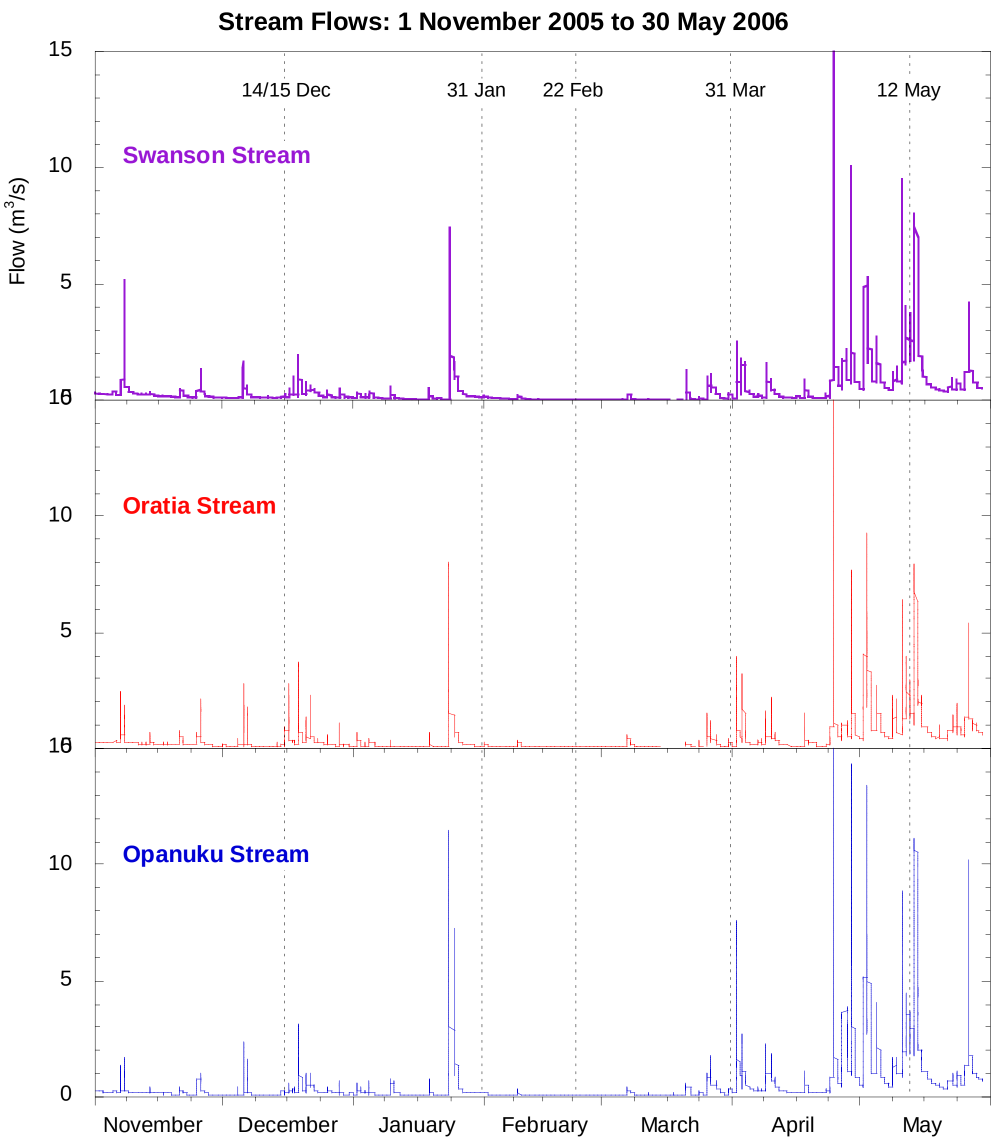


Figure 2.3 Stream flows between 1 November 2005 and 31 May 2006. Water quality sampling dates are shown as dotted lines.

2.3 Parameters measured

The following water quality parameters were measured:

- ammonia (NH_4-N), nitrite (NO_2-N), nitrate (NO_3-N), total oxidised nitrogen (NOx-N), dissolved reactive phosphorus (DRP), dissolved zinc (Zn) and dissolved copper (Cu) were analysed by R.J. Hill Laboratories (Hamilton);
- E. coli was measured by Aqualab NZ Ltd (Auckland).
- Temperature was recorded using electronic data loggers anchored at each site over the period between 1 February and 19 May 2006. These loggers recorded temperature every 30 minutes, giving an essentially continuous record comprising several thousand readings. These data enable the diurnal fluctuations in temperature to be assessed, and a more reliable assessment of the daytime maxima (which can potentially affect aquatic life) to be made.

2.3 Data analysis

Raw data are appended (Appendix 1). Summary statistics are given in Appendix 2. Data have been presented in the report as “box and whisker plots” (usually referred to as box plots) as described in Figure 2.4. These plots conveniently show the essential features of the data and enable clear visual comparison of sites or variables.

Each box encloses 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population (upper and lower quartiles). The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point (open circle). Outliers are values that are either greater than upper quartile (UQ) + 1.5 * IQR (interquartile range) or less than LQ − 1.5 * IQR.

Note that values below analytical detection limits (<D.L.s) have been replaced by values of 0.5 times the detection limit (0.5x D.L.) before plotting or calculating statistics. This is standard practice in water quality data analysis, and enables the low values to be included in analysis and interpretation without unduly biasing the results. The analytes where the number of <D.L. values were significant were nitrite, ammonia, copper and zinc.

One “greater than” value was recorded for E. coli at site M on 31 January 2006. This was treated as being equal to the maximum value measured (i.e. >24,200 E. coli/100 mL was treated as 24,200). These assumptions make no practical difference to the interpretation of the results.

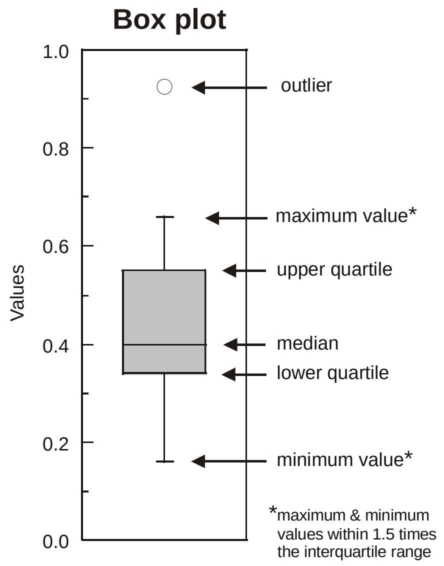


Figure 2.4 Interpretation of a box plot

3 Water Quality Monitoring Results from 2005–6

The following sections describe the water quality conditions over summer 2005–2006, including comparison with guidelines and spatial trends along each of the streams. Raw data are appended in Appendix 1 and a statistical summary is given in Appendix 2.

3.1 Temperature

Temperature data from the "continuous" data loggers are shown in Figure 3.1. Figure 3.2 shows the temperature records for upstream and downstream sites in each of the Oratia, Opanuku, Waikumete, and Swanson Streams. Summary statistics for the temperatures are included in Appendix 2.

Note that temperature was not recorded at sites O and P because the loggers were removed (washed away or stolen) during the monitoring period.

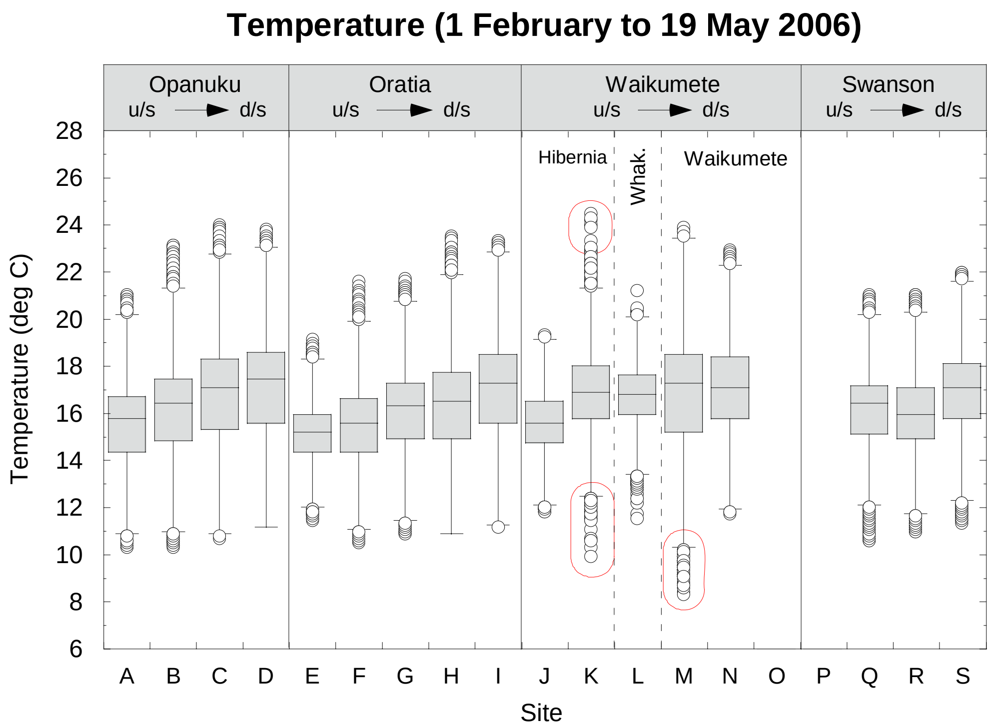


Figure 3.1 Stream water temperatures taken from continuous measurements between 1 February and 19 May 2006. The low outliers (○) at sites K and M, and possibly some higher outliers at site K were due to data loggers being out of the water, and are not reliable indicators of minimum (or maximum) temperatures at these sites.

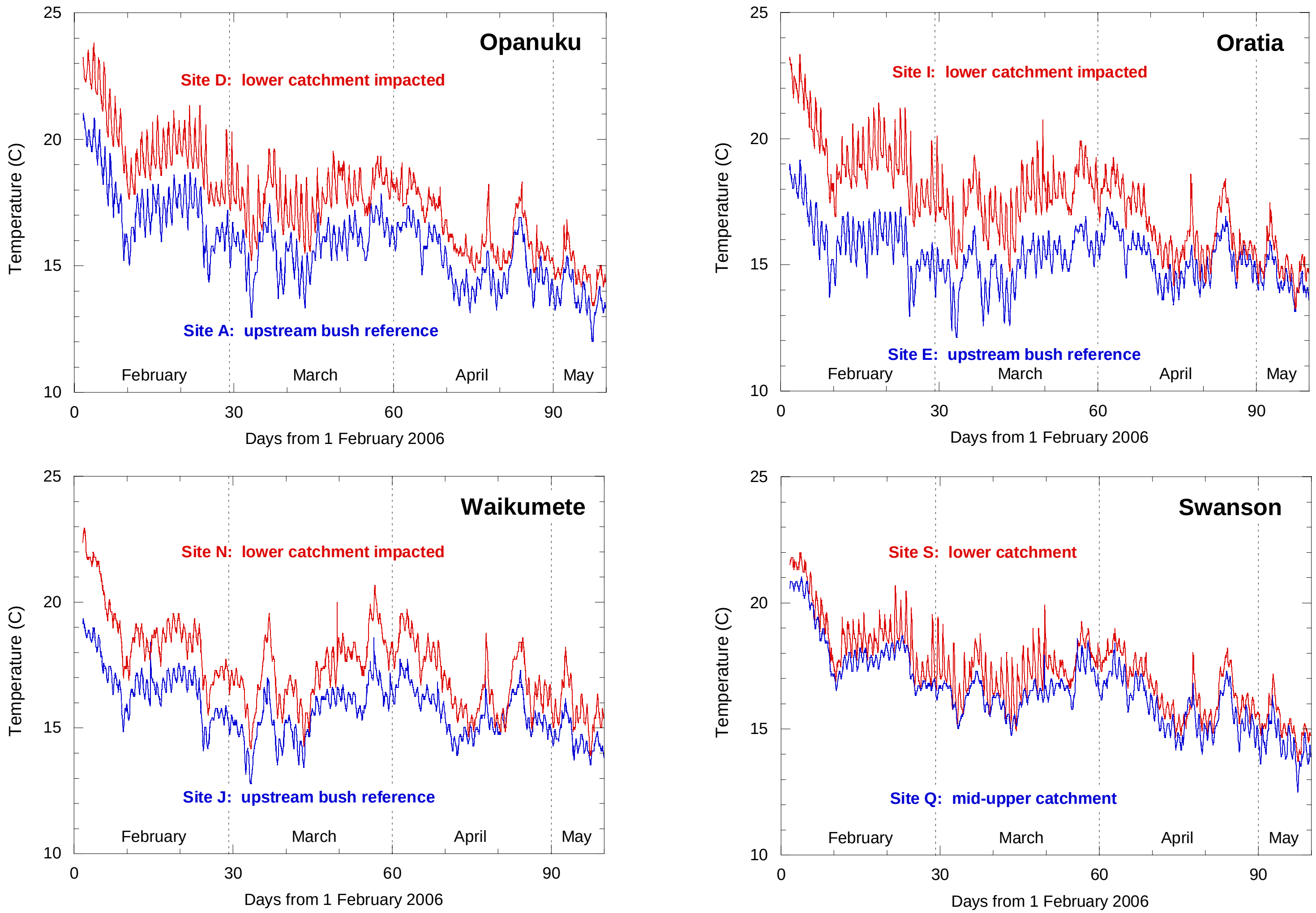


Figure 3.2 Temperature in the upper and lower catchment sites of the Opanuku, Oratia, Waikumete, and Swanson Streams between February and May 2006

Water temperatures increased from the upstream reference sites to the impacted lower sites in all four stream systems but, as was found in 2003-4, these changes were not large. Median temperature increases were about 1.7, 2.1, 1.5, and 0.7 ºC for the Opanuku, Oratia, Waikumete, and Swanson Streams respectively. Increases in maximum temperatures were somewhat larger, increasing by approximately 3–4ºC in the Oratia, Opanuku, and Waikumete Streams, and by approximately 1ºC in the Swanson Stream (although this was between the mid-upper catchment site Q and the lower catchment site S).

The relatively small changes in median and maximum temperatures, and in temperature ranges, between the headwaters and the lower sites indicate generally good shading is present in these streams.

The greatest temperature differences between upper and lower catchment sites were recorded in the Oratia Stream, and the least in the Swanson. Temperature differences were greatest in February (and were probably even greater again in January, before data collection began) and declined over time (Figure 3.3). This effect was most pronounced in the Oratia Stream and least in the Swanson (possibly because the difference was measured from a mid-catchment rather than upper catchment reference site). These data suggest that January and February (and possibly December) are the key times for potential thermal effects, and such effects are of relatively little consequence at other times

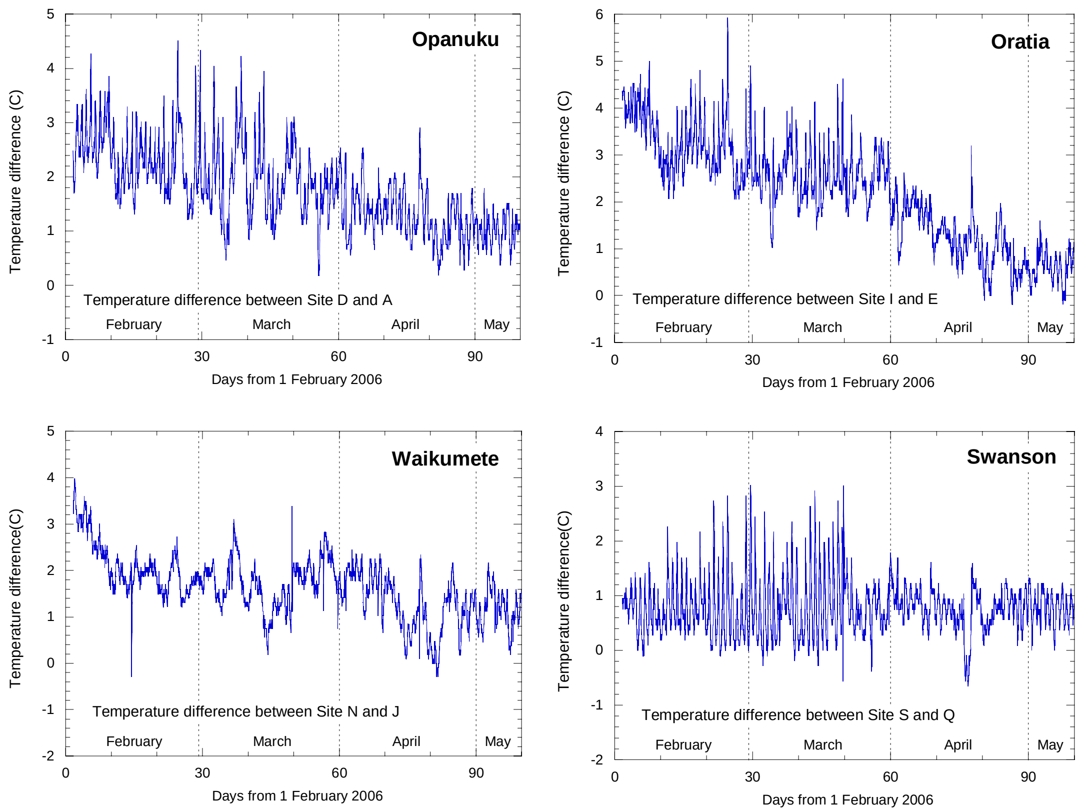


Figure 3.3 Differences in stream temperatures between upper and lower catchment sites in the four stream systems.

The temperature record showed that for at least 90% of the time, temperatures were below 20°C, which is below the level at which ecological effects might begin to occur (somewhere between 20 and 25°C depending on species and duration of exposure). Maximum temperatures reached approximately 24ºC at site C in the Opanuku Stream, and at site K in the Waikumete (although this may have been affected by data logger problems). However, temperatures between February and May 2006 were at this level for <1% of the time.

The data show that for the 2005–6 period between February and May 2006, ecologically stressful temperatures would be limited to very infrequent periods during low flows. This is consistent with the data collected in summer 2003-4 (EVA et al. 2004).

Summary: Temperature

Stream water temperatures over summer 2005–2006 were similar to those recorded in 2003–4 and were generally below those that should adversely affect aquatic life. However, no records were obtained in December or January, when temperatures may have been higher.

Changes within the catchment were relatively small, indicating effective present-day stream shading and little impact from land use changes. Greatest changes occurred in the Oratia Stream, where temperatures increased by about 4ºC. This stream would therefore benefit most from improved riparian shading.

3.2 Ammonia

Ammonia contributes to the nitrogenous nutrient content, which may lead to excessive in-stream aquatic plant growth. At high concentrations, ammonia can be toxic to aquatic life. High ammonia levels may also indicate sewage inputs.

As found in 2003–4, concentrations of ammonia were very low in the Oratia and Opanuku Streams. There were small increases with distance below the headwater sites, but concentrations were still well below ecological toxicity guidelines (approximately 0.9 mg/L NH_4-N at pH 8 and typical stream temperatures) at all sites (Figure 3.4).

A marked increase in ammonia occurred in the Hibernia Stream between the headwater site (J) and Ceramco Park (site K). Wastewater inputs are the most likely cause although anaerobic sediments are possible contributors. The highest value was measured at site K in December.

Concentrations of ammonia were slightly elevated at site L (Whakarino Stream at Withers Park) indicating only minor wastewater inputs into this tributary during the monitoring period. Levels at site M (Waikumete Stream below the confluence of Hibernia, Bishop, and Whakarino Streams) were somewhat elevated, reflecting the effects of inputs from the Hibernia Stream.

The Swanson Stream had moderately elevated ammonia concentrations, comparable with the Waikumete Stream, and substantially higher than the Oratia and Opanuku Streams.

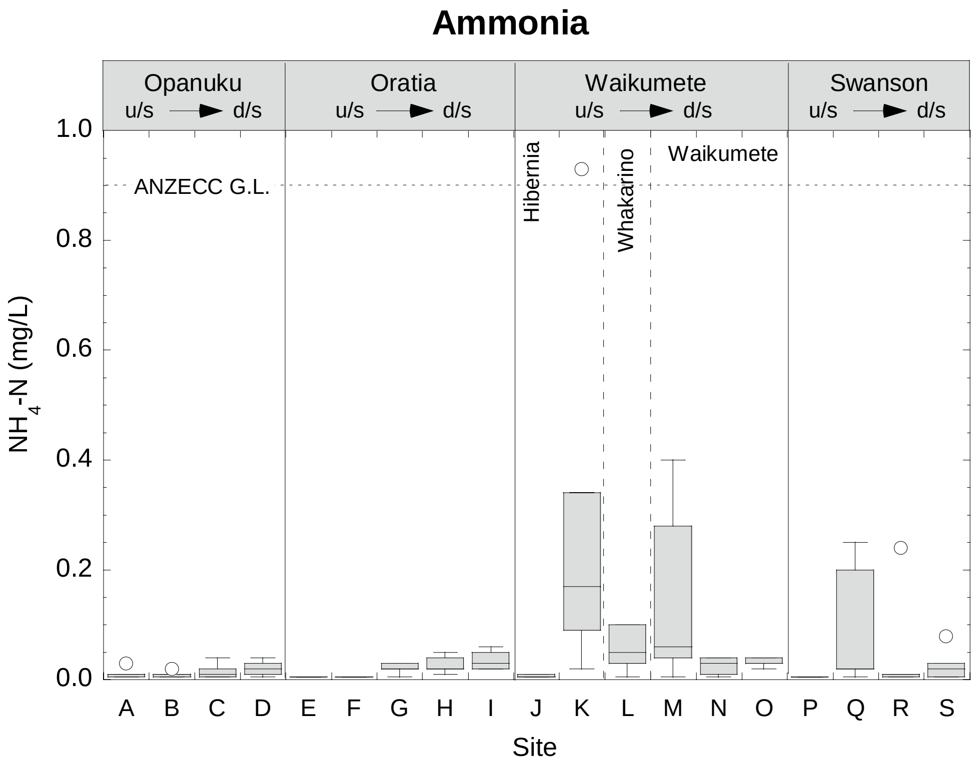


Figure 3.4 Ammonia levels in the Project Twin Streams catchment stream waters

Summary: Ammonia

Ammonia levels were well below toxic concentrations at all sites, although one sample reached the threshold at site K (Hibernia Stream, Ceramco Park).

Small increases in ammonia occurred at sites affected by rural and urban land use, but these are of little practical importance for stream water quality.

The highest ammonia levels were present at Ceramco Park in the Hibernia Stream. This is presumably due to wastewater inputs in the upstream urban reach.

Moderately elevated concentrations were present further downstream in the Waikumete Stream, and in the Swanson Stream.

The main effect of ammonia is likely to be a small addition to nutrient levels in the stream waters. Short-term toxic concentrations could potentially occur in the Waikumete Stream at times.

3.3 Dissolved copper and zinc

Dissolved zinc (Zn) and copper (Cu) were the only trace metals measured. Inputs of Cu and, more particularly, Zn from stormwater are rising in many urban areas, as evidenced by increasing concentrations in sediments in urban estuaries (ARC 2004). Their potential toxicity poses a risk to aquatic life in streams and estuaries.

Lead (Pb), another major urban contaminant, was not measured in the stream waters because Pb is very strongly bound to particulate matter, and therefore concentrations of dissolved Pb are generally very low in natural waters (usually below detection limits – e.g. NIWA 2005). Concentrations of Pb in Auckland's estuarine sediments are dropping over time (ARC 2004) probably in response to removal of key sources of Pb, such as from petrol in 1996

Dissolved metal, which is operationally defined as the fraction passing through a 0.45 μm filter, was measured because this provides a better measure of the biologically available concentration of the metal than "total" metal (which includes less available metals bound to suspended solids). Dissolved metals are also less variable than total metals because they are less affected by variations in suspended solids levels.

Guidelines & trigger values

We compared metals' concentrations with ANZECC (2000) guidelines. Note that the ANZECC (2000) guideline trigger values for metals applies to "total" metals' concentrations in the first instance. If total concentrations exceed the trigger values, then a more detailed investigation is warranted. The next step is to assess "dissolved metal" concentrations, because these more closely approximate the bioavailable (and hence potentially toxic) metal fraction. If dissolved concentrations exceed the trigger values, then even more detailed measurements, such as chemical speciation analysis or modelling, are required to fully assess whether toxicity is likely to occur.

The ANZECC metals' trigger levels were derived using *chronic* toxicity data, and are therefore appropriate for assessing the potential adverse effects that may occur from longer-term, low level exposure to contaminants during base flow conditions (as targeted in the PTS programme). Short-term acute toxicity effects may occur at higher concentrations during storm events or spills. The USEPA (2002) criteria include an acute toxicity value that can be used to assess potential short-term impacts.

The ANZECC guidelines provide metals' trigger values for four different levels of ecosystem protection, providing protection to 99%, 95%, 90%, and 80% of aquatic species. The default trigger value for "slightly–moderately disturbed" ecosystems is the 95% species protection level. The 99% level may apply to systems with high conservation value (e.g. the native forest reference sites), while lower levels of protection may be more suited to more highly disturbed or degraded systems (e.g. lower catchment urban sites). The management goals for the water bodies or reaches determine which levels of protection, and hence which trigger values, are most appropriate.

ANZECC trigger values for Cu range from 1.0–2.5 μg/L (for 99%–80% species protection respectively), while Zn trigger values are 2.4–31 μg/L. These ranges are shown in Figure 3.5. USEPA acute criteria have also been included for comparison.

Copper & zinc concentrations

Concentrations of Zn and Cu increased below the headwaters of all the stream systems (Figure 3.5a & b). Largest increases were observed for Zn in the Hibernia and Waikumete stream systems, with a large increase occurring between sites J (Waerenga Place) and K (Ceramco Park). The unusual data distribution observed for Cu and Zn at site G is a consequence of a missed analysis in January, resulting in only 4 results (rather then the 5 recorded at the other sites).

Highest concentrations (the high outliers in Figure 3.5a & b) occurred when the streams were at highest flows, during the 12th May sampling. This is indicative of the effects of greater inflows from stormwater drainage systems in urban areas and ephemeral streams in rural areas, which would normally not be flowing during 'true' base flow, as well as greater inputs from groundwater.

Median Cu concentrations were below the ANZECC 99% protection level at all the upper catchment reference sites (except site J on the Hibernia Stream), and at the rural sites F (Oratia Stream) and Q (Swanson Stream). Concentrations at the other sites were generally between the 80% and 99% levels. This indicates that during base flows, <10% of aquatic species should be adversely affected by Cu at most rural sites, while at the urban sites around 10–20% of species could be affected. Site M had the highest median Cu concentration – at this site >20% of species could be affected.

Highest concentrations were recorded during the high flow event (May sampling) at the rural and peri-urban sites in the Oratia Stream. This may reflect Cu inputs from horticultural land in this stream catchment. During higher flows (at indicated by the 12th May sampling results), Cu approached (and for some sites, exceeded) the USEPA (2002) criterion for acute toxicity at the rural and urban sites. This indicates the possibility of acute effects during storm runoff events.

Concentrations of Zn were below the ANZECC 99% protection level at the reference and rural sites (except site J). The ANZECC 95% protection trigger value was exceeded at all urban sites, except for sites R and S on the Swanson Stream. Highest Zn concentrations were present in the Waikumete Stream system, where concentrations were generally between the 90% and 80% protection levels.

As found for Cu, highest concentrations occurred during the higher flow sampling round on 12th May, reflecting the effects of stormwater inputs. Zinc concentrations were above the USEPA (2002) acute toxicity criteria in the Waikumete Stream (and downstream of the confluence with the Oratia at site I) at this time.

These results indicate that Zn concentrations in the water column during base flows are likely to affect <1% of aquatic species at the reference and rural sites, and >5–20% of species at urban sites. Acute toxicity may occur during storm events at urban sites, particularly in the Waikumete Stream system.

Whether these effects actually occur or not depends on the length of time that metals' concentrations are elevated, the flora and fauna actually present in the stream and their susceptibility to these contaminants, and the effect of water chemistry on the dissolved metals bioavailability (ANZECC 2000). Rural runoff in the Oratia catchment is a potential source of elevated Cu, while urban stormwater is having a significant impact on Zn concentrations.

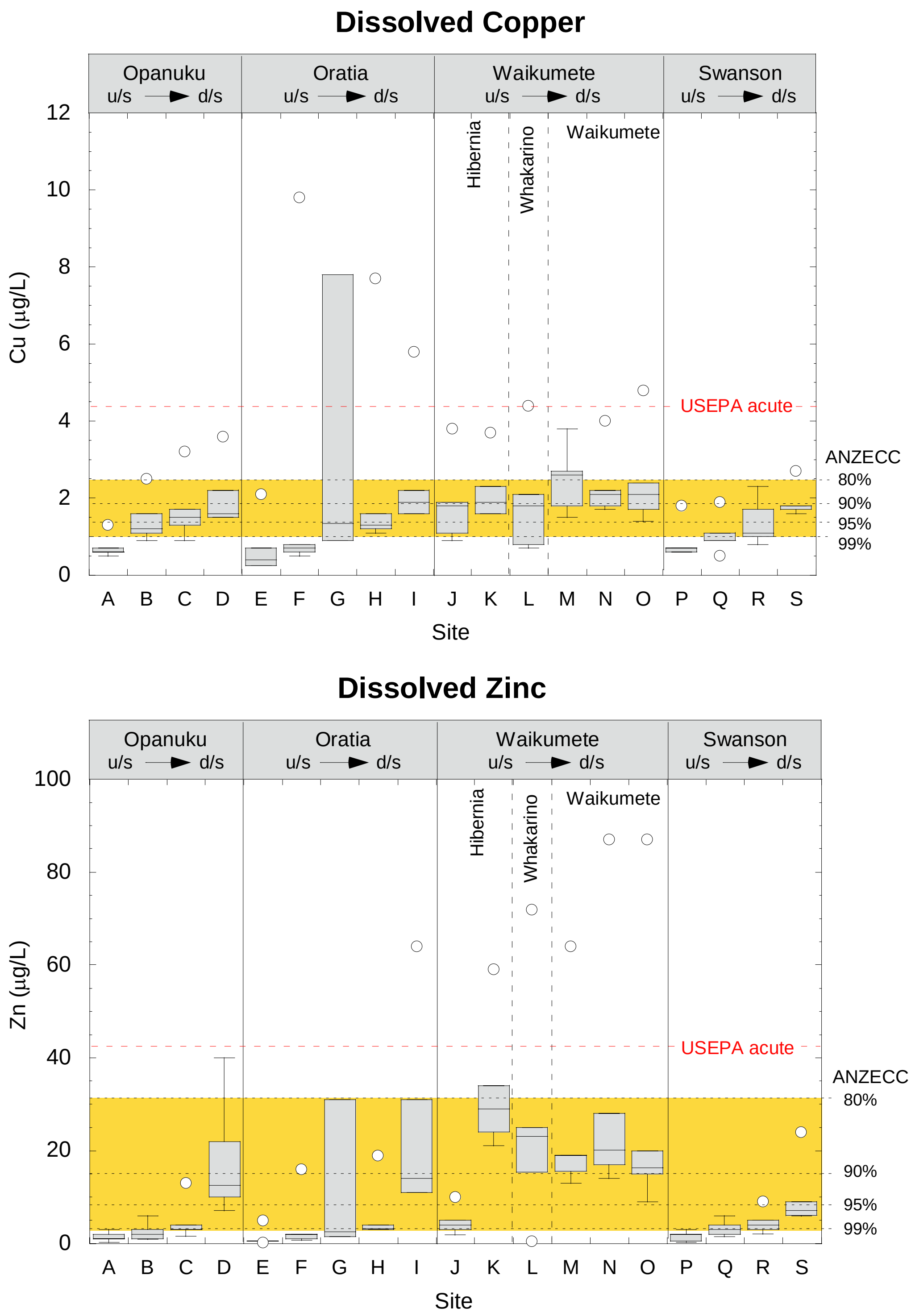


Figure 3.5 Dissolved copper and zinc concentrations in the PTS catchment stream waters. The unusual data distribution at site G is due to one fewer data points than the other sites. ANZECC trigger values (yellow) and USEPA acute criteria (red) shown for comparison.

Summary: Copper and zinc

Dissolved Cu concentrations increased with distance below the stream headwaters in all four catchments. Concentrations were highest at urban sites, which all had similar Cu concentrations.

Dissolved Zn concentrations were generally lowest in the Oratia and Opanuku Streams, and highest in the Waikumete Stream system.

Copper and Zn concentrations were highest during the high flow event sampling in May 2006 – levels exceeded USEPA acute toxicity thresholds at some sites on this occasion. Highest Cu concentrations were found in the rural and peri-urban sites in the Oratia catchment, possibly reflecting the effects of runoff from horticultural land. Highest Zn concentrations occurred at urban sites, indicative of stormwater inputs.

The data suggest Cu and Zn exceed concentrations that may adversely affect stream life in some rural and most urban areas, especially during times of elevated flows (when acute toxicity may occur). Chronic toxicity effects may affect up to 20% of aquatic species at urban sites during base flows.

3.4 Bacteria

The recommended indicator organism for assessing potential human health risks associated with contact recreation in freshwaters is *Escherichia coli* (E. coli; MFE 2003). E. coli counts are shown in Figure 3.6. Because the data are so variable (a normal feature of bacterial water quality data) they have been plotted on normal and logarithmic scales to show spatial changes and to allow comparison with guidelines.

Bacterial indicator levels increased from headwaters to downstream reaches of the Oratia and Opanuku Streams, mostly between the upper catchment reference sites and the peri-urban sites. A similar pattern was found for the Swanson Stream, with a substantial increase between sites P (which had the lowest indicator levels of all the monitoring sites) and Q. Levels were similar in the urban and peri-urban sites, suggesting that urban inputs were relatively small during the monitoring period.

The Hibernia/Waikumete Stream system showed a significant urban response, with a large increase in bacterial contamination between the bush-living headwaters (site J) and the downstream urban areas (sites K, L, M, N, and O). This occurred without the transition through rural areas, as occurs in the Opanuku, Oratia, and Swanson streams. The most contaminated site was site L, the Whakarino Stream at Withers Reserve.

There was no consistent pattern of bacterial levels between samplings, the highest counts occurring at various times at the different sites. The high counts at sites L and I occurred on 22nd February, while the maximum at site M occurred on 31st January. Levels were generally highest at the Opanuku sites in May during the higher flows, but this was not consistently observed in the Oratia, Waikumete, or Swanson Streams.

Although the amounts of data are limited, and the relevance of small urban streams for contact recreation is uncertain, an indication of the suitability for contact

recreation can be assessed using the process described in MFE (2003). The Microbiological Assessment Category (MAC) of the sites during the sampling period were estimated to be as follows[2]:

- none of the sites would have been classed as A or B;
- the headwater sites A, E, and J are probably class C, while the headwaters of the Swanson (site P) might (just) be B; and
- all rural and urban sites would fall into class D.

Using the Sanitary Inspection Categories (SIC) summarised in Figure H3 of MFE (2003), which would probably rate the headwater sites as having low susceptibility to faecal contamination, the rural sites as moderate, and the urban sites as high, the following suitability for contact recreation grades (Table E2, MFE 2003) would result:

- headwater sites P, A, E, and J would probably rate as fair (possibly good);
- rural sites would be largely fair-to-poor; and
- urban sites would rate as very poor.

Summary: Indicator Bacteria

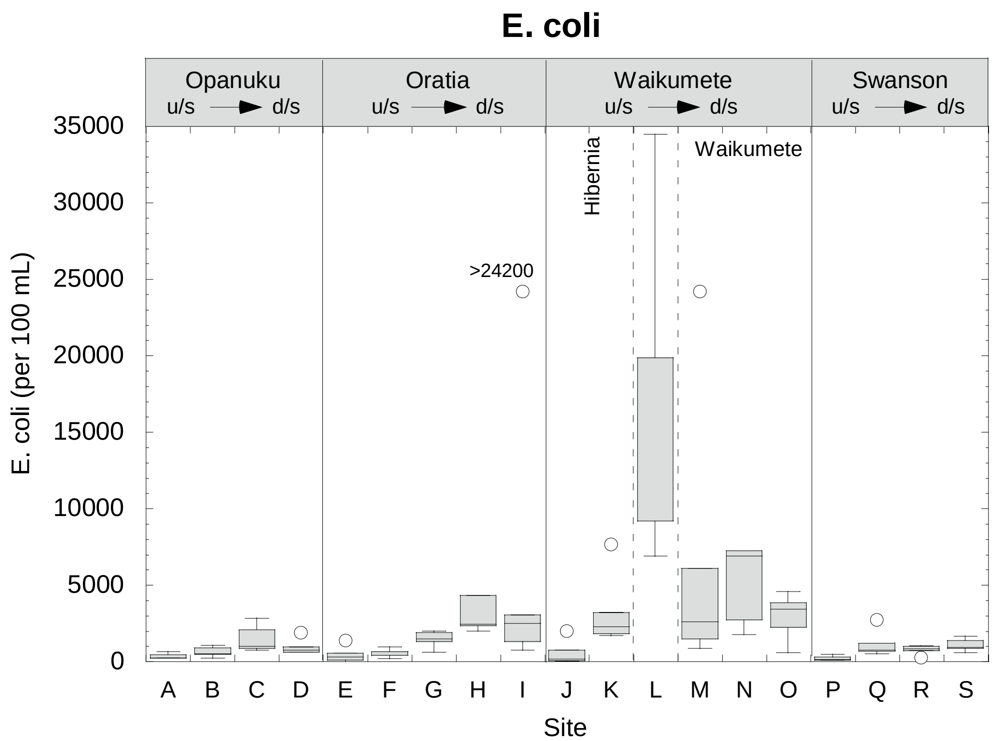
E. coli increased from headwaters to lower catchment sites. Large increases occurred upstream of the urban areas in the Swanson, Opanuku, and Oratia Streams, with little change below the urban-rural fringe.

Highest levels were present in the Waikumete Stream system, in particular the Whakarino Stream and may be indicative of waste water overflows.

Headwater sites would appear to rate as being fair-good for contact recreation, rural sites are probably only fair-poor, and urban sites very poor.

Data were highly variable, especially at the urban sites, so trends over time will only be detectable if large changes occurred between monitoring periods.

[2] Note that a reliable assessment requires much more data than available here, and that the 95%iles of the E. coli counts are used to determine the MAC (MFE 2003).



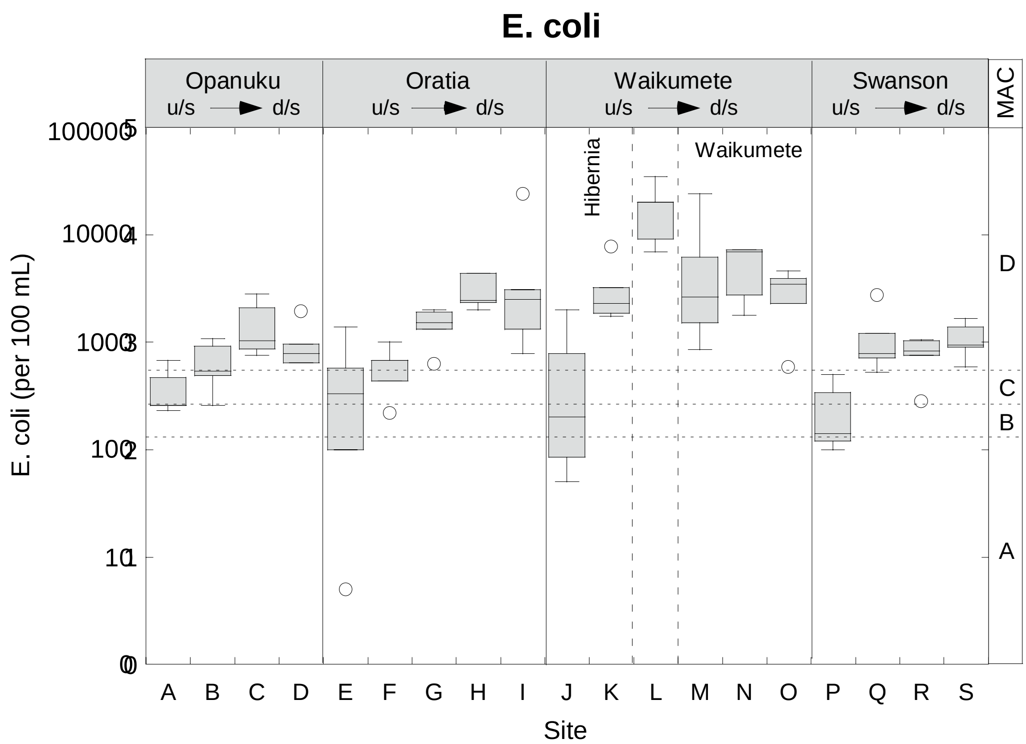


Figure 3.6 Indicator bacteria (E. coli) in the PTS catchment streams. The lower plot shows the data on a logarithmic scale to enable comparison with the Microbiological Assessment Category (MAC) in the MFE (2003) guidelines for contact recreation.

3.5 Nutrients

Nutrient inputs are not necessarily a major issue in urban streams. The process of urbanisation can lead to an increase or decrease in nutrient levels, depending on the previous land use. The urbanisation of the mid-lower catchment in the Twin Streams catchment might be expected to result in small decreases in nutrient levels because the land being developed is largely rural (pastoral and horticultural). However, this has not occurred so far, as outlined below.

The principal plant nutrients measured were nitrate (NO_3-N) and dissolved reactive phosphorus (DRP). Nitrite (NO_2-N) and ammonia (NH_4-N) also contribute to the nutrient load, but are only significant contributors in waters contaminated by sewage. The total oxidised nitrogen (NO_X-N), which is the sum of nitrate and nitrite (largely nitrate at most sites), has also been plotted because it can be compared with the ANZECC (2000) guideline to assess potential for nuisance growths arising from nitrogen enrichment.

Nitrate and nitrite concentrations are shown in Figure 3.7. NO_X-N and DRP are shown in Figure 3.8, and ammonia was discussed previously (section 3.2, Figure 3.4).

Nitrate

Nitrate levels generally increased with distance downstream from the headwater sites. The exception was the headwaters of the Oratia Stream (Site E; Potters Stream, Bendall's Lane), where nitrate concentrations were somewhat higher than they were further downstream. DRP levels were also unusually high at site E (Figure 3.8). This was also found in the 2003–4 monitoring.

Nitrate concentrations at all sites below the headwaters in the Swanson Stream were elevated compared with the Opanuku and Oratia Streams, and were even slightly higher than in the Waikumete Stream. There is clearly a source of N-enrichment in the Swanson Stream, probably associated with rural land use.

Nitrate (and NO_X-N) levels were generally higher at the urban sites than in the upstream rural sites. This indicates a significant nitrogen source from urban activity, or possibly the residual effects of N-enriched ground water inputs originating from pre-urbanisation rural land use.

Highest concentrations were present in the May sampling, where higher flows reflect greater runoff.

Total oxidised nitrogen

Total oxidised nitrogen levels followed the same spatial patterns as nitrate. Concentrations were mostly below ANZECC guidelines at all sites except for site K (Hibernia Stream at Ceramco Park), which also had elevated nitrite and ammonia concentrations (compared with other sites). Highest concentrations were recorded in May, associated with higher flows and greater runoff.

Nitrite

Nitrite nitrogen levels were generally very low – near to, or below, detection limits – at most sites. Elevated levels were recorded in the Hibernia Stream at site K (Ceramco Park) and downstream at site M (Waikumete at Glendale Rd). High nitrate, and ammonia were also recorded at site K, suggesting sewage inputs may be

significant to the upstream reach. E. coli were also high, although not as high as at sites L or N.

Nitrite levels in the Swanson Stream were slightly elevated at sites below the headwaters, comparable with those in the lower Waikumete Stream system.

Phosphorus

Dissolved phosphorus levels were generally low in the Opanuku, Waikumete and Swanson Streams. As was observed in the 2003–4 monitoring, the headwaters of the Oratia Stream had substantially higher DRP levels, which declined with distance downstream (Figure 3.8). There was no clear evidence of elevated DRP levels in urban stream reaches.

Apart from the Oratia Stream sites discussed above, DRP levels were generally close to, or below, ANZECC guidelines.

Summary: Nutrients

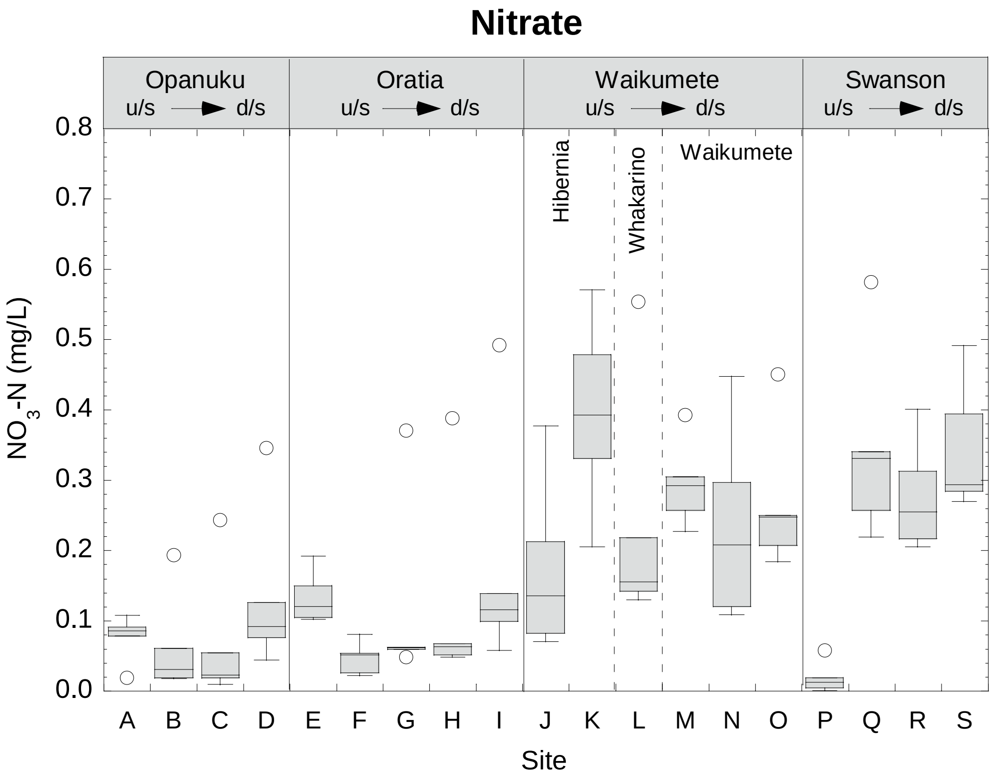
Nitrate and oxidised nitrogen levels were generally highest at urban sites in the Waikumete Stream system, and in the rural–urban reaches of the Swanson Stream. Highest concentrations occurred during the higher flows of May 2006.

Total oxidised nitrogen levels were below ANZECC guidelines for nuisance growths at all sites except the Hibernia Stream at Ceramco Park (site K).

Dissolved phosphorus concentrations were generally low, except for in the headwaters of the Oratia Stream (Potters Stream). Apart from this, DRP concentrations were generally below guideline levels.

Nitrite concentrations were generally low, but there are appreciable levels in the Hibernia Stream, suggesting sewage inputs above site K.

Overall, nitrogen enrichment is evident in the Swanson Stream and Waikumete Stream system, while phosphorus is significantly elevated in the headwaters of the Oratia Stream (Potters Stream).



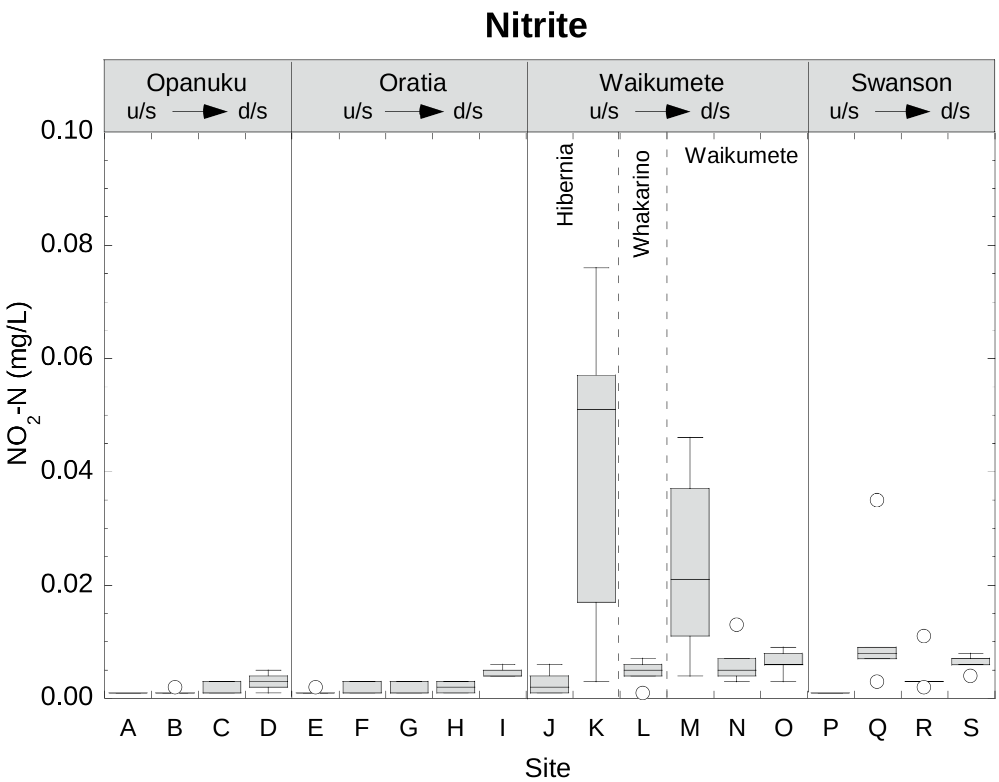
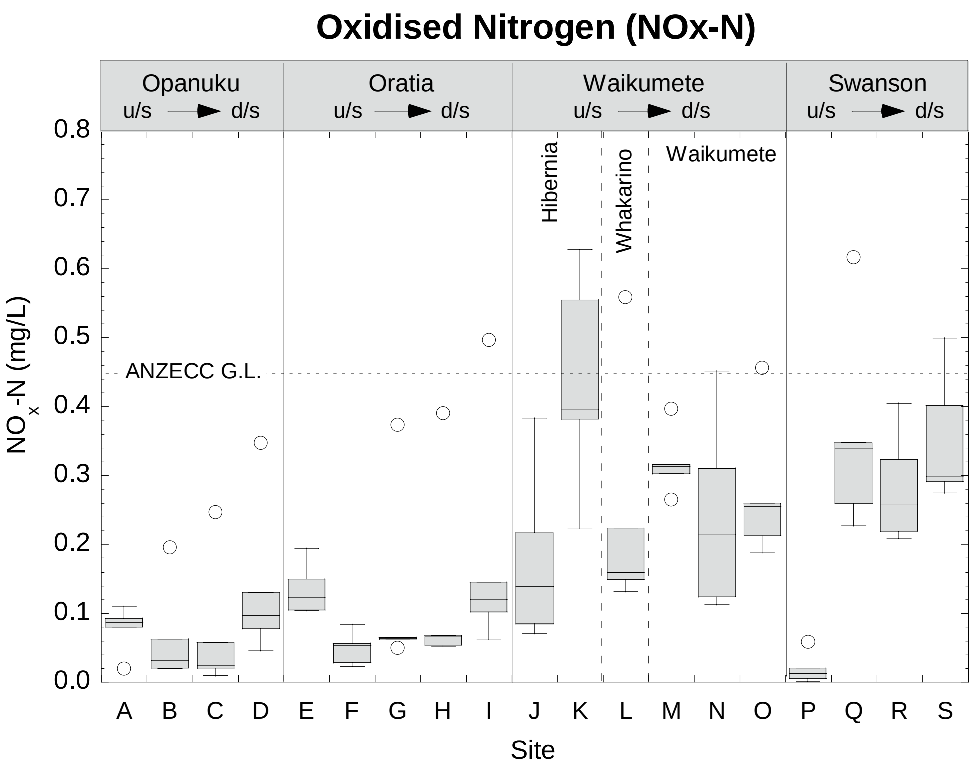


Figure 3.7 Nitrate and nitrite nitrogen levels in the Project Twin Streams catchment.



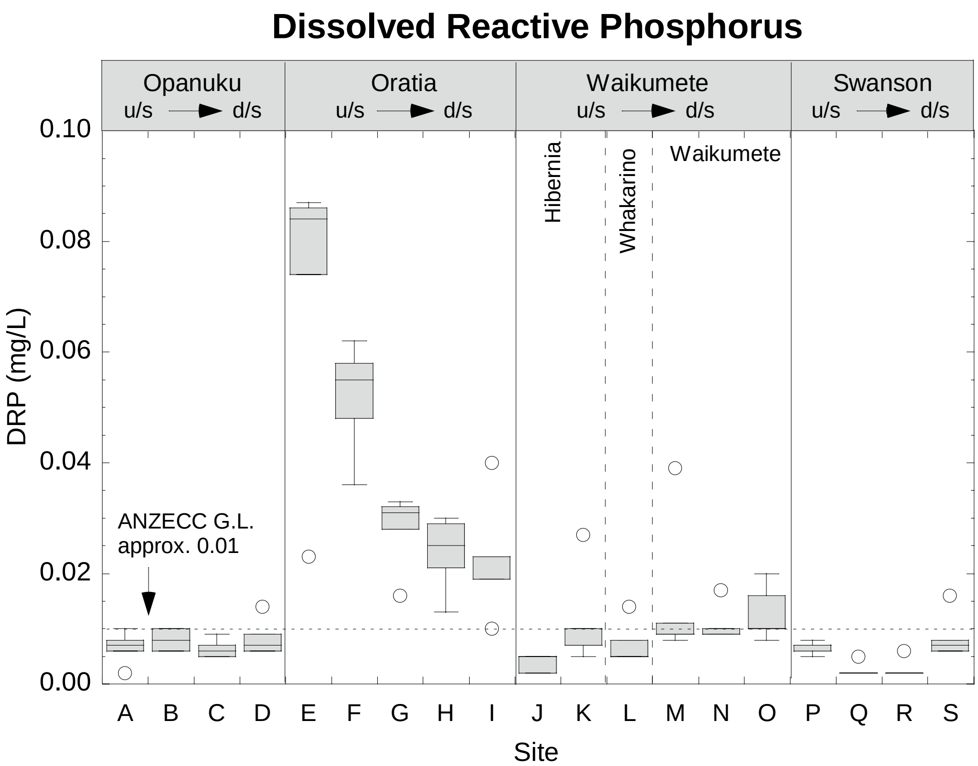


Figure 3.8 Total oxidised nitrogen and dissolved reactive phosphorus levels in the Project Twin Streams catchment.

4 Comparison with 2003–4 monitoring data

Water quality varies substantially over time, in response to a wide range of factors including runoff, season, stream flows, spills, and changing catchment land use. Assessing changes over time is usually done by analysing long-term data records, generally over periods of a decade or more. These long periods are usually required because the data often show high variability and semi-regular seasonal fluctuations, which must be taken into account when measuring the magnitude, direction, and significance of trends over time.

Assessment of short-term changes can be done, but it is important to realise that the "changes" may not be part of on-going trends – they may be just part of the variability inherent in water quality data, or short-term responses to catchment inputs or stream flow variations.

Bearing this caution in mind, data from the 2005–6 monitoring has been compared with that obtained from the summer 2003–4 monitoring to assess whether the same general patterns in water quality have been recorded and the magnitude and nature of any differences. The sensitivity of these comparisons is limited by the small numbers of samples (generally 5 from 2003–4 and 6 from 2005–6) and the high variability in much of the data.

This exercise provides useful information on the consistency of the data collected to date, and highlights major differences between the monitoring periods. However, it cannot determine the causes of any observed differences – catchment pressure information is required for this (and will be included in future analyses in 2008–9).

4.1 Stream flows

Stream flow is a major influencing factor on water quality. High flows reflect additional inputs from rural and urban runoff, and water quality is often poorer at these times. Conversely, low flows can result in more elevated temperatures, and lower dissolved oxygen levels.

It is therefore worthwhile comparing stream flow conditions in each of the monitoring periods to determine whether variable flows are likely to have some influence on water quality.

A comparison of stream flows on the sampling dates in each summer period is given in Table 4.1, using data from ARC flow monitoring stations (see section 2.2 for locations).

These data show that stream flows on the sampling dates were quite different in each monitoring period – generally lower in 2005–6 for December – February, varied in March, and much higher in April/May.

The effect of the higher flow in the May 2006 sampling was seen in higher nitrate (and oxidised nitrogen) and dissolved Cu and Zn concentrations.

Table 4.1 Stream flows (m^3/s) on sampling dates in summer 2003–4 and 2005–6[1]. Data are from ARC flow monitoring sites.

	Opanuku		Oratia		Swanson	
Sampling Month	2003–4	2005–6	2003–4	2005–6	2005–6	2005-6 cf 2003-4
December	0.17	0.095	0.21	0.096	0.105	Lower
January	0.17 1.25	0.134	0.54 1.64	0.120	0.136	Lower
February	0.20 0.80	0.080	0.23 0.73	0.057	0.025	Lower
March/April	0.09 0.08	0.207	0.15	0.088	0.107	Higher in Opanuku Lower in Opanuku
April/May	0.05 0.19	3.02	0.09 0.23	2.80	2.64	Much higher

1. Sampling was undertaken over two days in January–April 2004, hence two different stream flows. This was reduced to one day in 2005–6 sampling.

4.2 Water quality

Comparison of 2003–4 and 2005–6 water quality was made using the non-parametric Kruskall Wallis test, which examines the distribution of the data and tests the significance of the difference between median values.

The results of these comparisons are shown graphically in Figures 4.1a & b.

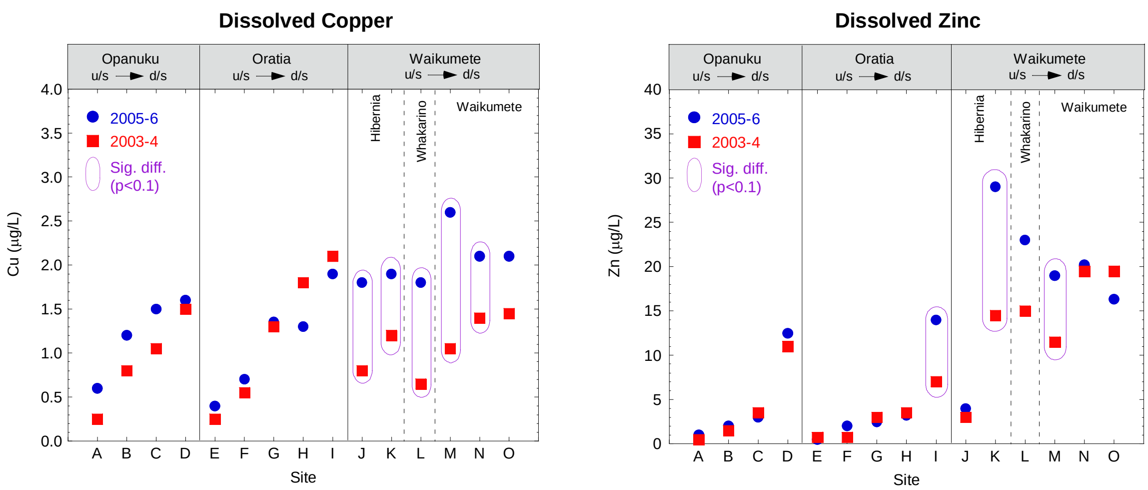


Figure 4.1a Comparison of median water quality in summer 2003–4 and 2005–6. Significant differences (Kruskall Wallis test, corrected p<0.1) are highlighted.

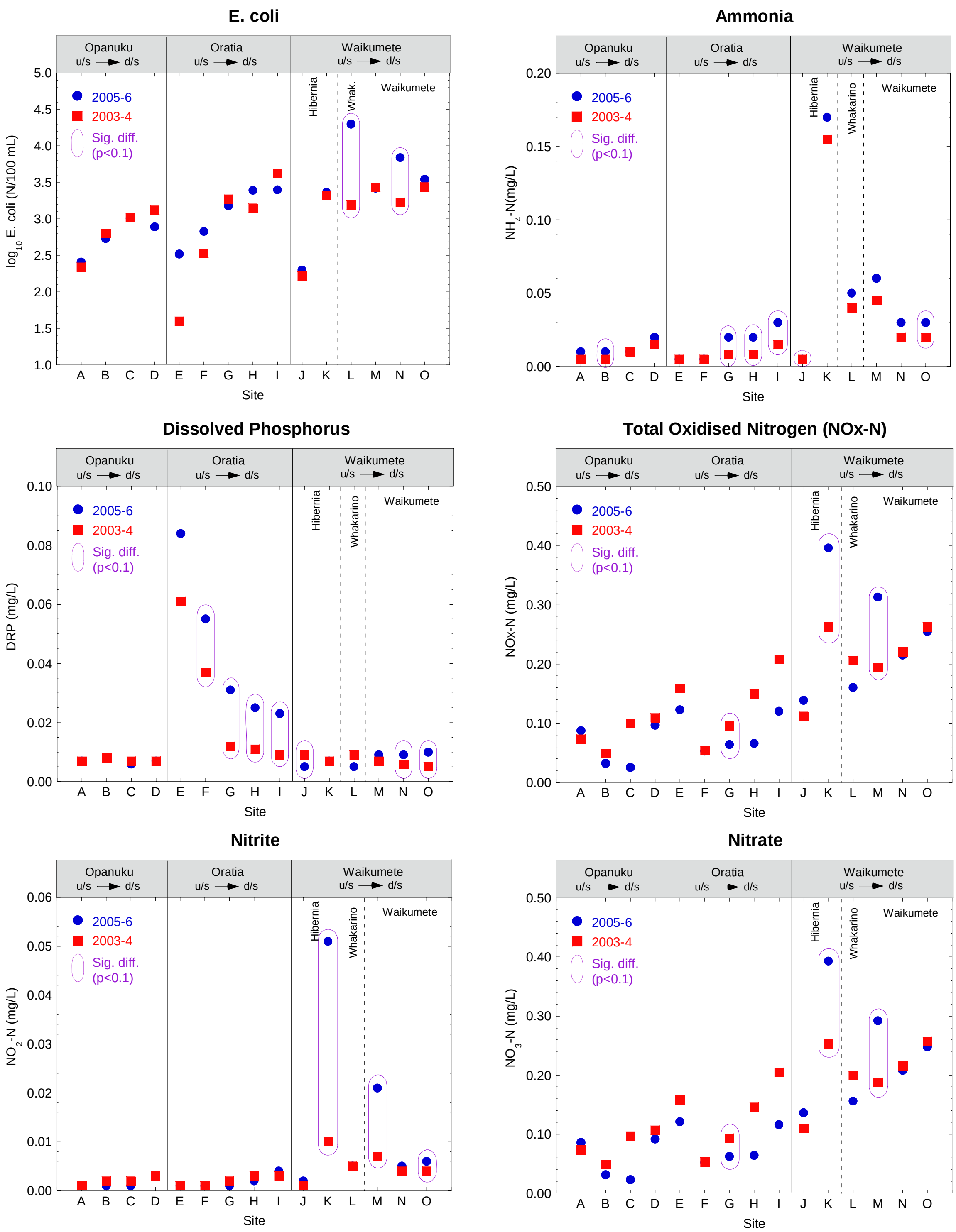


Figure 4.1b Comparison of median water quality in summer 2003–4 and 2005–6. Significant differences (Kruskall Wallis test, p<0.1) are highlighted.

These comparisons show that the spatial patterns in water quality in the PTS catchments were similar in 2003–4 and 2005–6.

Differences in water quality were observed for:

- dissolved Cu and Zn in the Waikumete Stream system, where concentrations were generally higher in 2005–6 than in 2003–4.
- Dissolved phosphorus, where concentrations were higher in the Oratia Stream, and lower Waikumete Stream, in 2005–6 than in 2003–4.
- E. coli at two sites (Whakarino, site L and Waikumete, site N) which were higher in 2005–6 than in 2003–4.
- Ammonia, which was generally higher at all sites in 2005–6 (even if not statistically so at all sites).
- Nitrite, nitrate, and oxidised nitrogen, which were higher in 2005–6 at sites K and M. Conversely nitrate and oxidised nitrogen levels were somewhat lower in 2005–6 in the Oratia Stream.

Examination of Figures 4.1a & b reveals that some differences in median concentrations are quite large, which is a reflection of the inherent variability in many water quality variables, differences in stream flows between samplings, and the generally low concentrations of many of the measured values.

Overall, most of the large differences occurred in the Waikumete Stream system. This probably reflects the greater susceptibility of the small streams in this system to changes associated with runoff and overflows, and the greater pressures in this catchment.

5 Summary and Recommendations

5.1 Summary

Water quality monitoring was undertaken at 19 sites in the Opanuku, Oratia, Waikumete, and Swanson Stream systems at approximately monthly intervals between December 2005 and May 2006.

Spatial patterns in water quality were similar to those recorded in the last monitoring conducted in summer 2003–4.

Temperature changes within the catchment were relatively small, increasing gradually with distance below the streams' headwaters. Maximum temperatures reached 24 ºC in exposed lower catchment sites, but only briefly. Generally temperatures were below 20 ºC for more than 90% of the time. Based on the data collected, adverse in-stream ecological effects from elevated temperatures seem unlikely.

Ammonia levels were low, mostly below levels considered to be toxic to aquatic life. Elevated levels were notable in the Hibernia Stream near Ceramco Park (site K), and further downstream in the Waikumete Stream (site M), probably due to wastewater inputs. The Swanson Stream site Q also had moderately elevated ammonia compared with other sites.

Zinc and copper levels increased with distance below the headwaters of the Oratia, Opanuku, and Swanson Streams. The largest changes occurred between the peri-urban and urban sites, indicating urban runoff is the major contributor to elevated Zn levels. Zn concentrations were highest in the Waikumete Stream system, exceeding ANZECC (2000) guidelines at urban sites, but were below USEPA toxicity guidelines. Copper levels exceeded ANZECC (2000) guidelines at urban and peri-urban sites and approached (and sometimes exceeded) USEPA toxicity guidelines at the urban sites.

Bacteria were, as expected, highly variable, and showed an increasing trend with distance below the headwater sites in all three stream systems. Highest levels in the Oratia and Opanuku streams were measured at the peri-urban sites. Urban sites in the Waikumete Stream system had the highest bacterial counts. Based on these results, bacterial water quality at all sites below the headwaters is probably unsuitable for contact recreation. Low microbiological water quality occurs in both rural and urban areas.

Nitrogen and phosphorus nutrients showed different spatial trends in the different stream systems. Nitrogen (mainly nitrate) concentrations were highest in the Waikumete and Swanson Streams, and considerably lower in the Oratia and Opanuku. Urban effects were greater in the Oratia, Opanuku, and Waikumete Streams, while concentrations increased markedly in the rural reaches of the Swanson Stream.

Phosphorus levels were generally low throughout the catchment, except in the headwaters of the Oratia (Potters Stream). There was no observable "urban effect" for phosphorus.

Nitrite levels were low at all sites except at Ceramco Park in the Hibernia Stream, and further downstream at Glendale Rd (Waikumete Stream). This is indicative of the effect of wastewater inputs.

Overall, the Opanuku and Oratia streams generally have higher water quality than the Waikumete Stream system. This is evident in lower levels of dissolved Zn, nitrate (and oxidised nitrogen), nitrite, and ammonia in the Oratia and Opanuku streams. The Oratia Stream headwaters did, however, have elevated dissolved phosphorus levels – the source needs to be determined.

The Swanson Stream shows lower concentrations of Zn than the other streams, but Cu and E. coli levels were comparable with the Opanuku and Oratia Streams. The Swanson Stream did, however, show marked nitrate enrichment, and slightly elevated nitrite levels, at rural and urban sites.

Comparison of the summer 2005–6 monitoring data with that collected in 2003–4 showed reasonably consistent spatial patterns in water quality. Some differences were noted, mainly in nutrient and metals' concentrations in the Waikumete Stream system. These concentrations were generally higher in 2005–6 than in 2003–4, the last sampling in May 2006 being a contributor to this effect.

5.2 Recommendations

All the sites monitored gave useful information. It is important to continue to monitor them all. Effort should continue to be made to ensure base flow conditions are sampled each month to reduce data variability and improve comparability over time.

The next round of monitoring should be undertaken in summer 2008–9, beginning in November 2008 and ending in April 2009. Catchment pressure data for the period 2003–2009 will be required in order to interpret the water (and sediment) quality data collected in the programme.

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Appendix 1. Water Quality Monitoring Data

Site	Month	Date	Turbidity NTU	TSS mg/L	NH4-N mg/L	NO3N + NO2N mg/L	NO3-N mg/L	NO2-N mg/L	DRP mg/L	Cu mg/L	Zn mg/L	E. coli N/100 mL	Cond mS/m	pH pH units
A	Dec	15-Dec-05	1.45	< 3	< 0.01	0.087	0.086	< 0.002	0.006	0.0006	< 0.0005	230	14.0	7.1
B	Dec	15-Dec-05	2.5	< 3	0.02	0.032	0.031	< 0.002	0.006	0.0011	0.0009	490	15.2	7.2
C	Dec	15-Dec-05	4.3	6	0.04	0.010	0.010	< 0.002	0.005	0.0013	0.0016	760	15.8	7.1
D	Dec	15-Dec-05	6.33	8	0.04	0.097	0.092	0.005	0.007	0.0016	0.0125	640	17.8	6.9
E	Dec	15-Dec-05	1.39	< 3	< 0.01	0.123	0.121	< 0.002	0.084	0.0004	< 0.0005	570	26.2	7.9
F	Dec	15-Dec-05	2.78	4	< 0.01	0.053	0.052	< 0.002	0.055	0.0008	0.0007	990	24.0	7.6
G	Dec	15-Dec-05	4.59	4	0.03	0.065	0.063	< 0.002	0.032	0.0013	0.0015	1330	22.0	7.3
H	Dec	15-Dec-05	8.02	9	0.05	0.068	0.068	< 0.002	0.029	0.0013	0.0032	2480	21.9	7.2
I	Dec	15-Dec-05	8.68	10	0.03	0.103	0.099	0.004	0.019	0.0019	0.0110	770	22.5	7.1
J	Dec	15-Dec-05	15.4	8	0.01	0.383	0.377	0.006	< 0.004	0.0019	0.0019	2010	25.0	7.3
K	Dec	15-Dec-05	14.6	9	0.93	0.382	0.331	0.051	0.027	0.0019	0.0240	3250	21.7	6.7
L	Dec	15-Dec-05	11.2	7	0.05	0.132	0.130	< 0.002	0.005	0.0008	0.0154	9210	20.2	7.0
M	Dec	15-Dec-05	29.9	22	0.40	0.303	0.257	0.046	0.009	0.0018	0.0156	2620	20.1	6.8
N	Dec	15-Dec-05	13.9	8	0.04	0.215	0.208	0.007	0.009	0.0022	0.0202	1780	20.3	7.0
O	Dec	15-Dec-05	14.4	10	0.04	0.259	0.250	0.009	0.010	0.0024	0.0163	590	20.6	7.0
P	Dec	14-Dec-05	5.05	< 3	< 0.01	0.006	0.005	< 0.002	0.008	0.0006	< 0.0005	500	18.7	7.1
Q	Dec	14-Dec-05	8.08	4	0.25	0.617	0.582	0.035	< 0.004	0.0009	0.0015	520	20.9	6.9
R	Dec	14-Dec-05	6.11	< 3	< 0.01	0.405	0.401	0.003	0.006	0.0010	0.0021	280	20.8	7.1
S	Dec	14-Dec-05	7.64	4	0.03	0.499	0.491	0.008	0.016	0.0017	0.0061	890	21.2	7.0

Appendix 1 continued…

Site	Month	Date	Turbidity NTU	TSS mg/L	NH4-N mg/L	NO3N + NO2N mg/L	NO3-N mg/L	NO2-N mg/L	DRP mg/L	Cu mg/L	Zn mg/L	E. coli N/100 mL	Cond mS/m	pH pH units
A	Jan/Feb	31-Jan-06	n.d.	n.d.	0.01	0.020	0.019	< 0.002	0.008	0.0006	0.0010	470	n.d.	n.d.
B	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.021	0.019	< 0.002	0.008	0.0009	0.0010	540	n.d.	n.d.
C	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.025	0.023	< 0.002	0.007	0.0015	0.0030	880	n.d.	n.d.
D	Jan/Feb	31-Jan-06	n.d.	n.d.	0.01	0.078	0.076	0.003	0.009	0.0015	0.0100	640	n.d.	n.d.
E	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.104	0.103	< 0.002	0.074	< 0.0005	< 0.001	100	n.d.	n.d.
F	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.029	0.026	0.003	0.048	0.0006	0.0010	220	n.d.	n.d.
G	Jan/Feb	31-Jan-06	n.d.	n.d.	0.02	0.064	0.062	< 0.002	0.031	n.d.	n.d.	1500	n.d.	n.d.
H	Jan/Feb	31-Jan-06	n.d.	n.d.	0.02	0.066	0.064	0.002	0.025	0.0012	0.0030	2360	n.d.	n.d.
I	Jan/Feb	31-Jan-06	n.d.	n.d.	0.02	0.120	0.116	0.004	0.023	0.0016	0.0110	1330	n.d.	n.d.
J	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.071	0.071	< 0.002	0.005	0.0011	0.0030	85	n.d.	n.d.
K	Jan/Feb	31-Jan-06	n.d.	n.d.	0.09	0.224	0.206	0.017	0.007	0.0016	0.0210	1860	n.d.	n.d.
L	Jan/Feb	31-Jan-06	n.d.	n.d.	0.10	0.160	0.156	0.004	0.005	0.0007	< 0.001	19860	n.d.	n.d.
M	Jan/Feb	31-Jan-06	n.d.	n.d.	0.28	0.265	0.227	0.037	0.039	0.0015	0.0130	> 24200	n.d.	n.d.
N	Jan/Feb	31-Jan-06	n.d.	n.d.	0.03	0.310	0.297	0.013	0.017	0.0018	0.0170	2760	n.d.	n.d.
O	Jan/Feb	31-Jan-06	n.d.	n.d.	0.04	0.255	0.248	0.008	0.016	0.0017	0.0150	2280	n.d.	n.d.
P	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.013	0.013	< 0.002	0.007	0.0006	< 0.001	100	n.d.	n.d.
Q	Jan/Feb	31-Jan-06	n.d.	n.d.	0.02	0.339	0.331	0.008	< 0.004	0.0009	0.0040	2760	n.d.	n.d.
R	Jan/Feb	31-Jan-06	n.d.	n.d.	0.01	0.257	0.255	0.003	< 0.004	0.0011	0.0030	1020	n.d.	n.d.
S	Jan/Feb	31-Jan-06	n.d.	n.d.	< 0.01	0.291	0.284	0.007	0.007	0.0018	0.0070	1380	n.d.	n.d.

Appendix 1 continued…

Site	Month	Date	Turbidity NTU	TSS mg/L	NH4-N mg/L	NO3N + NO2N mg/L	NO3-N mg/L	NO2-N mg/L	DRP mg/L	Cu mg/L	Zn mg/L	E. coli N/100 mL	Cond mS/m	pH pH units
A	Feb/Mar	22-Feb-06	n.d.	< 3	< 0.01	0.080	0.079	< 0.002	< 0.004	0.0005	0.0010	260	n.d.	n.d.
B	Feb/Mar	22-Feb-06	n.d.	< 3	< 0.01	0.020	0.018	< 0.002	0.006	0.0012	0.0030	260	n.d.	n.d.
C	Feb/Mar	22-Feb-06	n.d.	5	< 0.01	0.021	0.019	< 0.002	0.005	0.0009	0.0040	1020	n.d.	n.d.
D	Feb/Mar	22-Feb-06	n.d.	6	< 0.01	0.046	0.045	< 0.002	0.014	0.0015	0.0070	780	n.d.	n.d.
E	Feb/Mar	22-Feb-06	n.d.	< 3	< 0.01	0.150	0.150	< 0.002	0.087	0.0007	< 0.001	<10	n.d.	n.d.
F	Feb/Mar	22-Feb-06	n.d.	< 3	< 0.01	0.023	0.022	< 0.002	0.062	0.0005	0.0020	680	n.d.	n.d.
G	Feb/Mar	22-Feb-06	n.d.	4	< 0.01	0.050	0.049	< 0.002	0.028	0.0009	0.0020	630	n.d.	n.d.
H	Feb/Mar	22-Feb-06	n.d.	16	0.02	0.054	0.052	< 0.002	0.021	0.0011	0.0030	4350	n.d.	n.d.
I	Feb/Mar	22-Feb-06	n.d.	7	0.05	0.145	0.139	0.006	0.040	0.0016	0.0310	24200	n.d.	n.d.
J	Feb/Mar	22-Feb-06	n.d.	7	< 0.01	0.085	0.083	< 0.002	0.005	0.0009	0.0040	50	n.d.	n.d.
K	Feb/Mar	22-Feb-06	n.d.	19	0.34	0.555	0.479	0.076	0.010	0.0016	0.0290	1720	n.d.	n.d.
L	Feb/Mar	22-Feb-06	n.d.	73	0.03	0.224	0.218	0.006	0.005	0.0018	0.0250	34500	n.d.	n.d.
M	Feb/Mar	22-Feb-06	n.d.	12	< 0.01	0.313	0.292	0.021	0.008	0.0027	0.0190	1500	n.d.	n.d.
N	Feb/Mar	22-Feb-06	n.d.	8	< 0.01	0.124	0.121	0.003	0.009	0.0017	0.0140	7270	n.d.	n.d.
O	Feb/Mar	22-Feb-06	n.d.	11	0.03	0.188	0.184	0.003	0.010	0.0014	0.0090	3450	n.d.	n.d.
P	Feb/Mar	22-Feb-06	n.d.	< 3	< 0.01	< 0.002	< 0.002	< 0.002	0.006	0.0007	0.0020	140	n.d.	n.d.
Q	Feb/Mar	22-Feb-06	n.d.	3	< 0.01	0.260	0.257	0.003	0.005	0.0005	0.0020	700	n.d.	n.d.
R	Feb/Mar	22-Feb-06	n.d.	3	< 0.01	0.209	0.206	0.003	< 0.004	0.0008	0.0050	840	n.d.	n.d.
S	Feb/Mar	22-Feb-06	n.d.	4	< 0.01	0.299	0.294	0.006	0.006	0.0016	0.0060	590	n.d.	n.d.

Appendix 1 continued…

Site	Month	Date	Turbidity NTU	TSS mg/L	NH4-N mg/L	NO3N + NO2N mg/L	NO3-N mg/L	NO2-N mg/L	DRP mg/L	Cu mg/L	Zn mg/L	E. coli N/100 mL	Cond mS/m	pH pH units
A	Mar/Apr	31-Mar-06	n.d.	n.d.	0.03	0.093	0.091	< 0.002	0.010	0.0007	0.0020	260	n.d.	n.d.
B	Mar/Apr	31-Mar-06	n.d.	n.d.	0.01	0.063	0.061	0.002	0.010	0.0016	0.0020	910	n.d.	n.d.
C	Mar/Apr	31-Mar-06	n.d.	n.d.	0.02	0.058	0.055	0.003	0.009	0.0017	0.0030	2100	n.d.	n.d.
D	Mar/Apr	31-Mar-06	n.d.	n.d.	0.03	0.130	0.126	0.004	0.006	0.0022	0.0220	960	n.d.	n.d.
E	Mar/Apr	31-Mar-06	n.d.	n.d.	< 0.01	0.105	0.105	< 0.002	0.086	< 0.0005	< 0.001	330	n.d.	n.d.
F	Mar/Apr	31-Mar-06	n.d.	n.d.	< 0.01	0.056	0.054	< 0.002	0.058	0.0007	0.0020	440	n.d.	n.d.
G	Mar/Apr	31-Mar-06	n.d.	n.d.	0.03	0.063	0.060	0.003	0.033	0.0014	0.0030	2010	n.d.	n.d.
H	Mar/Apr	31-Mar-06	n.d.	n.d.	0.04	0.052	0.049	0.003	0.030	0.0016	0.0040	4350	n.d.	n.d.
I	Mar/Apr	31-Mar-06	n.d.	n.d.	0.06	0.063	0.058	0.004	0.023	0.0022	0.0140	2500	n.d.	n.d.
J	Mar/Apr	31-Mar-06	n.d.	n.d.	< 0.01	0.139	0.136	0.002	< 0.004	0.0018	0.0050	200	n.d.	n.d.
K	Mar/Apr	31-Mar-06	n.d.	n.d.	0.17	0.628	0.571	0.057	0.007	0.0023	0.0340	7700	n.d.	n.d.
L	Mar/Apr	31-Mar-06	n.d.	n.d.	< 0.01	0.149	0.142	0.007	0.008	0.0021	0.0230	6900	n.d.	n.d.
M	Mar/Apr	31-Mar-06	n.d.	n.d.	0.06	0.316	0.305	0.011	0.011	0.0026	0.0190	860	n.d.	n.d.
N	Mar/Apr	31-Mar-06	n.d.	n.d.	0.01	0.113	0.109	0.004	0.010	0.0021	0.0280	6900	n.d.	n.d.
O	Mar/Apr	31-Mar-06	n.d.	n.d.	0.03	0.213	0.207	0.006	0.020	0.0021	0.0200	4600	n.d.	n.d.
P	Mar/Apr	31-Mar-06	n.d.	n.d.	< 0.01	0.021	0.019	< 0.002	0.007	0.0007	0.0020	120	n.d.	n.d.
Q	Mar/Apr	31-Mar-06	n.d.	n.d.	0.02	0.348	0.341	0.007	< 0.004	0.0011	0.0030	1200	n.d.	n.d.
R	Mar/Apr	31-Mar-06	n.d.	n.d.	0.01	0.219	0.217	0.002	< 0.004	0.0017	0.0040	750	n.d.	n.d.
S	Mar/Apr	31-Mar-06	n.d.	n.d.	0.02	0.275	0.270	0.004	0.008	0.0018	0.0090	930	n.d.	n.d.

Appendix 1 continued…

Site	Month	Date	Turbidity NTU	TSS mg/L	NH4-N mg/L	NO3N + NO2N mg/L	NO3-N mg/L	NO2-N mg/L	DRP mg/L	Cu mg/L	Zn mg/L	E. coli N/100 mL	Cond mS/m	pH pH units
A	May	12-May-06	n.d.	n.d.	0.01	0.110	0.108	< 0.002	0.007	0.0013	0.0030	680	n.d.	n.d.
B	May	12-May-06	n.d.	n.d.	0.01	0.196	0.194	< 0.002	0.010	0.0025	0.0060	1080	n.d.	n.d.
C	May	12-May-06	n.d.	n.d.	0.01	0.247	0.244	0.003	0.006	0.0032	0.0130	2850	n.d.	n.d.
D	May	12-May-06	n.d.	n.d.	0.02	0.348	0.346	0.002	0.006	0.0036	0.0400	1930	n.d.	n.d.
E	May	12-May-06	n.d.	n.d.	< 0.01	0.195	0.192	0.002	0.023	0.0021	0.0050	1380	n.d.	n.d.
F	May	12-May-06	n.d.	n.d.	< 0.01	0.084	0.081	0.003	0.036	0.0098	0.0160	680	n.d.	n.d.
G	May	12-May-06	n.d.	n.d.	0.02	0.374	0.371	0.003	0.016	0.0078	0.0310	1920	n.d.	n.d.
H	May	12-May-06	n.d.	n.d.	0.01	0.391	0.388	0.003	0.013	0.0077	0.0190	2010	n.d.	n.d.
I	May	12-May-06	n.d.	n.d.	0.02	0.497	0.492	0.005	0.010	0.0058	0.0640	3080	n.d.	n.d.
J	May	12-May-06	n.d.	n.d.	0.01	0.217	0.213	0.004	0.005	0.0038	0.0100	770	n.d.	n.d.
K	May	12-May-06	n.d.	n.d.	0.02	0.396	0.393	0.003	0.005	0.0037	0.0590	2310	n.d.	n.d.
L	May	12-May-06	n.d.	n.d.	0.10	0.559	0.554	0.005	0.014	0.0044	0.0720	19860	n.d.	n.d.
M	May	12-May-06	n.d.	n.d.	0.04	0.397	0.393	0.004	0.009	0.0038	0.0640	6130	n.d.	n.d.
N	May	12-May-06	n.d.	n.d.	0.04	0.452	0.448	0.005	0.009	0.0040	0.0870	7270	n.d.	n.d.
O	May	12-May-06	n.d.	n.d.	0.02	0.456	0.451	0.006	0.008	0.0048	0.0870	3870	n.d.	n.d.
P	May	12-May-06	n.d.	n.d.	< 0.01	0.059	0.058	< 0.002	0.005	0.0018	0.0030	340	n.d.	n.d.
Q	May	12-May-06	n.d.	n.d.	0.20	0.227	0.219	0.009	< 0.004	0.0019	0.0060	770	n.d.	n.d.
R	May	12-May-06	n.d.	n.d.	0.24	0.323	0.313	0.011	< 0.004	0.0023	0.0090	1050	n.d.	n.d.
S	May	12-May-06	n.d.	n.d.	0.08	0.402	0.395	0.007	0.006	0.0027	0.0240	1670	n.d.	n.d.

Appendix 2. Water Quality Summary Statistics

All less than detection limit data replaced by 0.5 x D.L. before calculating statistics

Dissolved Cu (μg/L, ppb)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.74	0.6	0.321	0.103	0.8	0.5	1.3	0.275	0.575	0.85
B	5	1.46	1.2	0.635	0.403	1.6	0.9	2.5	0.775	1.05	1.825
C	5	1.72	1.5	0.879	0.772	2.3	0.9	3.2	0.875	1.2	2.075
D	5	2.08	1.6	0.898	0.807	2.1	1.5	3.6	1.05	1.5	2.55
E	5	0.74	0.4	0.782	0.612	1.85	0.25	2.1	0.8	0.25	1.05
F	5	2.48	0.7	4.094	16.757	9.3	0.5	9.8	2.475	0.575	3.05
G	4	2.85	1.35	3.307	10.937	6.9	0.9	7.8	3.5	1.1	4.6
H	5	2.58	1.3	2.868	8.227	6.6	1.1	7.7	1.95	1.175	3.125
I	5	2.62	1.9	1.795	3.222	4.2	1.6	5.8	1.5	1.6	3.1
J	5	1.9	1.8	1.147	1.315	2.9	0.9	3.8	1.325	1.05	2.375
K	5	2.22	1.9	0.876	0.767	2.1	1.6	3.7	1.05	1.6	2.65
L	5	1.96	1.8	1.494	2.233	3.7	0.7	4.4	1.9	0.775	2.675
M	5	2.48	2.6	0.898	0.807	2.3	1.5	3.8	1.25	1.725	2.975
N	5	2.36	2.1	0.94	0.883	2.3	1.7	4	0.875	1.775	2.65
O	5	2.48	2.1	1.352	1.827	3.4	1.4	4.8	1.375	1.625	3
P	5	0.88	0.7	0.517	0.267	1.2	0.6	1.8	0.375	0.6	0.975
Q	5	1.06	0.9	0.518	0.268	1.4	0.5	1.9	0.5	0.8	1.3
R	5	1.38	1.1	0.614	0.377	1.5	0.8	2.3	0.9	0.95	1.85
S	5	1.92	1.8	0.444	0.197	1.1	1.6	2.7	0.35	1.675	2.025

Dissolved Zn (μg/L, ppb)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	1.45	1.0	1.067	1.138	2.75	0.25	3	1.438	0.813	2.25
B	5	2.58	2.0	2.093	4.382	5.1	0.9	6	2.775	0.975	3.75
C	5	4.92	3.0	4.597	21.132	11.4	1.6	13	3.6	2.65	6.25
D	5	18.3	12.5	13.368	178.7	33	7	40	17.25	9.25	26.5
E	5	1.35	0.5	2.043	4.175	4.75	0.25	5	1.188	0.438	1.625
F	5	4.34	2.0	6.544	42.828	15.3	0.7	16	4.575	0.925	5.5
G	4	9.375	2.5	14.43	208.229	29.5	1.5	31	15.25	1.75	17
H	5	6.44	3.2	7.033	49.468	16	3	19	4.75	3	7.75
I	5	26.2	14.0	22.709	515.7	53	11	64	28.25	11	39.25
J	5	4.78	4.0	3.137	9.842	8.1	1.9	10	3.525	2.725	6.25
K	5	33.4	29.0	15.143	229.3	38	21	59	17	23.25	40.25
L	5	27.18	23.0	26.84	720.412	71.5	0.5	72	25.075	11.675	36.75
M	5	26.12	19.0	21.325	454.772	51	13	64	15.3	14.95	30.25
N	5	33.24	20.2	30.502	930.388	73	14	87	26.5	16.25	42.75
O	5	29.46	16.3	32.408	1050.308	78	9	87	23.25	13.5	36.75
P	5	1.55	2.0	1.151	1.325	2.75	0.25	3	1.813	0.438	2.25
Q	5	3.3	3.0	1.789	3.2	4.5	1.5	6	2.625	1.875	4.5
R	5	4.62	4.0	2.678	7.172	6.9	2.1	9	3.225	2.775	6
S	5	10.42	7.0	7.686	59.082	18	6	24	6.675	6.075	12.75

Dissolved Reactive Phosphorus (DRP, mg/L)

SIte	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.0066	0.007	0.00297	8.80E-06	0.008	0.002	0.01	0.0035	0.005	0.0085
B	5	0.008	0.008	0.002	4.00E-06	0.004	0.006	0.01	0.004	0.006	0.01
C	5	0.0064	0.006	0.00167	2.80E-06	0.004	0.005	0.009	0.0025	0.005	0.0075
D	5	0.0084	0.007	0.00336	1.13E-05	0.008	0.006	0.014	0.00425	0.006	0.0102
E	5	0.0708	0.084	0.0272	7.41E-04	0.064	0.023	0.087	0.025	0.0612	0.0862
F	5	0.0518	0.055	0.0102	1.04E-04	0.026	0.036	0.062	0.014	0.045	0.059
G	5	0.028	0.031	0.00696	4.85E-05	0.017	0.016	0.033	0.00725	0.025	0.0323
H	5	0.0236	0.025	0.00691	4.78E-05	0.017	0.013	0.03	0.0103	0.019	0.0293
I	5	0.023	0.023	0.0109	1.19E-04	0.03	0.01	0.04	0.0105	0.0167	0.0273
J	5	0.0038	0.005	0.00164	2.70E-06	0.003	0.002	0.005	0.003	0.002	0.005
K	5	0.0112	0.007	0.00901	8.12E-05	0.022	0.005	0.027	0.00775	0.0065	0.0142
L	5	0.0074	0.005	0.00391	1.53E-05	0.009	0.005	0.014	0.0045	0.005	0.0095
M	5	0.0152	0.009	0.0133	1.78E-04	0.031	0.008	0.039	0.00925	0.00875	0.018
N	5	0.0108	0.009	0.00349	1.22E-05	0.008	0.009	0.017	0.00275	0.009	0.0118
O	5	0.0128	0.01	0.00502	2.52E-05	0.012	0.008	0.02	0.0075	0.0095	0.017
P	5	0.0066	0.007	0.00114	1.30E-06	0.003	0.005	0.008	0.0015	0.00575	0.00725
Q	5	0.0026	0.002	0.00134	1.80E-06	0.003	0.002	0.005	7.50E-04	0.002	0.00275
R	5	0.0028	0.002	0.00179	3.20E-06	0.004	0.002	0.006	0.001	0.002	0.003
S	5	0.0086	0.007	0.00422	1.78E-05	0.01	0.006	0.016	0.004	0.006	0.01

Temperature (data loggers)

SIte	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5117	15.55	15.78	1.84	3.37	10.72	10.32	21.04	2.34	14.37	16.71
B	5117	16.29	16.43	2.16	4.67	12.82	10.32	23.14	2.62	14.84	17.46
C	5117	16.96	17.09	2.33	5.44	13.31	10.70	24.01	3.00	15.31	18.31
D	5117	17.23	17.46	2.30	5.27	12.63	11.18	23.81	3.00	15.59	18.59
E	5117	15.14	15.21	1.26	1.59	7.69	11.46	19.15	1.59	14.37	15.96
F	5117	15.60	15.59	1.76	3.08	11.10	10.51	21.61	2.25	14.37	16.62
G	5117	16.20	16.34	1.81	3.29	10.82	10.89	21.71	2.35	14.93	17.28
H	5117	16.48	16.53	2.12	4.48	12.64	10.89	23.53	2.81	14.93	17.74
I	5117	17.16	17.28	2.13	4.54	12.15	11.18	23.33	2.91	15.59	18.50
J	5117	15.57	15.59	1.33	1.77	7.50	11.84	19.34	1.78	14.75	16.53
K	5117	16.92	16.90	1.87	3.49	14.55	9.94	24.49	2.25	15.78	18.03
L	5117	16.77	16.81	1.33	1.78	9.68	11.55	21.23	1.69	15.96	17.65
M	5117	16.82	17.28	2.61	6.83	15.59	8.32	23.91	3.29	15.21	18.50
N	5117	17.13	17.09	1.85	3.41	11.21	11.74	22.95	2.62	15.78	18.40
Q	5117	16.21	16.43	1.82	3.31	10.43	10.61	21.04	2.06	15.12	17.18
R	5117	16.04	15.96	1.72	2.94	10.05	10.99	21.04	2.16	14.93	17.09
S	5117	16.97	17.09	1.89	3.58	10.63	11.36	21.99	2.34	15.78	18.12

E coli (MPN/100 mL)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	380	260	193.261	37350	450	230	680	270	252.5	522.5
B	5	656	540	332.461	110530	820	260	1080	520	432.5	952.5
C	5	1522	1020	914.123	835620	2090	760	2850	1437.5	850	2287.5
D	5	990	780	541.664	293400	1290	640	1930	562.5	640	1202.5
E	5	477	330	550.132	302645	1375	5	1380	696.25	76.25	772.5
F	5	602	680	289.344	83720	770	220	990	372.5	385	757.5
G	5	1478	1500	552.241	304970	1380	630	2010	787.5	1155	1942.5
H	5	3110	2480	1145.06	1311150	2340	2010	4350	2077.5	2272.5	4350
I	5	6376	2500	10005.9	1E+08	23430	770	24200	7170	1190	8360
J	5	623	200	827.961	685520	1960	50	2010	1003.75	76.25	1080
K	5	3368	2310	2494.47	6222370	5980	1720	7700	2537.5	1825	4362.5
L	5	18066	19860	10950.1	1.2E+08	27600	6900	34500	14887.5	8632.5	23520
M	5	7062	2620	9794.28	95927920	23340	860	24200	9307.5	1340	10647.5
N	5	5196	6900	2697.67	7277430	5490	1780	7270	4755	2515	7270
O	5	2958	3450	1568.21	2459270	4010	590	4600	2195	1857.5	4052.5
P	5	240	140	174.356	30400	400	100	500	265	115	380
Q	5	1190	770	912.469	832600	2240	520	2760	935	655	1590
R	5	788	840	310.113	96170	770	280	1050	395	632.5	1027.5
S	5	1092	930	428.976	184020	1080	590	1670	637.5	815	1452.5

Ammonia (NH4-N, mg/L)

SIte	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.012	0.01	0.0104	1.08E-04	0.025	0.005	0.03	0.01	0.005	0.015
B	5	0.01	0.01	0.00612	3.75E-05	0.015	0.005	0.02	0.0075	0.005	0.0125
C	5	0.016	0.01	0.0147	2.18E-04	0.035	0.005	0.04	0.02	0.005	0.025
D	5	0.021	0.02	0.0143	2.05E-04	0.035	0.005	0.04	0.0238	0.00875	0.0325
E	5	0.005	0.005	0	0	0	0.005	0.005	0	0.005	0.005
F	5	0.005	0.005	0	0	0	0.005	0.005	0	0.005	0.005
G	5	0.021	0.02	0.0102	1.05E-04	0.025	0.005	0.03	0.0137	0.0163	0.03
H	5	0.028	0.02	0.0164	2.70E-04	0.04	0.01	0.05	0.025	0.0175	0.0425
I	5	0.036	0.03	0.0182	3.30E-04	0.04	0.02	0.06	0.0325	0.02	0.0525
J	5	0.007	0.005	0.00274	7.50E-06	0.005	0.005	0.01	0.005	0.005	0.01
K	5	0.31	0.17	0.367	0.134	0.91	0.02	0.93	0.415	0.0725	0.488
L	5	0.057	0.05	0.0424	0.0018	0.095	0.005	0.1	0.0763	0.0238	0.1
M	5	0.157	0.06	0.173	0.0301	0.395	0.005	0.4	0.279	0.0313	0.31
N	5	0.025	0.03	0.0166	2.75E-04	0.035	0.005	0.04	0.0313	0.00875	0.04
O	5	0.032	0.03	0.00837	7.00E-05	0.02	0.02	0.04	0.0125	0.0275	0.04
P	5	0.005	0.005	0	0	0	0.005	0.005	0	0.005	0.005
Q	5	0.099	0.02	0.117	0.0136	0.245	0.005	0.25	0.196	0.0163	0.213
R	5	0.054	0.01	0.104	0.0108	0.235	0.005	0.24	0.0625	0.005	0.0675
S	5	0.028	0.02	0.0309	9.58E-04	0.075	0.005	0.08	0.0375	0.005	0.0425

Nitrite (NO_2-N, mg/L)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001
B	5	0.0012	0.001	4.47E-04	2.00E-07	0.001	0.001	0.002	2.50E-04	0.001	0.00125
C	5	0.0018	0.001	0.0011	1.20E-06	0.002	0.001	0.003	0.002	0.001	0.003
D	5	0.003	0.003	0.00158	2.50E-06	0.004	0.001	0.005	0.0025	0.00175	0.00425
E	5	0.0012	0.001	4.47E-04	2.00E-07	0.001	0.001	0.002	2.50E-04	0.001	0.00125
F	5	0.0018	0.001	0.0011	1.20E-06	0.002	0.001	0.003	0.002	0.001	0.003
G	5	0.0018	0.001	0.0011	1.20E-06	0.002	0.001	0.003	0.002	0.001	0.003
H	5	0.002	0.002	0.001	1.00E-06	0.002	0.001	0.003	0.002	0.001	0.003
I	5	0.0046	0.004	8.94E-04	8.00E-07	0.002	0.004	0.006	0.00125	0.004	0.00525
J	5	0.0028	0.002	0.00217	4.70E-06	0.005	0.001	0.006	0.0035	0.001	0.0045
K	5	0.0408	0.051	0.03	9.00E-04	0.073	0.003	0.076	0.0483	0.0135	0.0617
L	5	0.0046	0.005	0.0023	5.30E-06	0.006	0.001	0.007	0.003	0.00325	0.00625
M	5	0.0238	0.021	0.0175	3.08E-04	0.042	0.004	0.046	0.03	0.00925	0.0392
N	5	0.0064	0.005	0.00397	1.58E-05	0.01	0.003	0.013	0.00475	0.00375	0.0085
O	5	0.0064	0.006	0.0023	5.30E-06	0.006	0.003	0.009	0.003	0.00525	0.00825
P	5	0.001	0.001	0	0	0	0.001	0.001	0	0.001	0.001
Q	5	0.0124	0.008	0.0128	1.65E-04	0.032	0.003	0.035	0.0095	0.006	0.0155
R	5	0.0044	0.003	0.00371	1.38E-05	0.009	0.002	0.011	0.00225	0.00275	0.005
S	5	0.0064	0.007	0.00152	2.30E-06	0.004	0.004	0.008	0.00175	0.0055	0.00725

Nitrate (NO_3-N, mg/L)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.0766	0.086	0.0339	0.00115	0.089	0.019	0.108	0.0313	0.064	0.0953
B	5	0.0646	0.031	0.0744	0.00553	0.176	0.018	0.194	0.0755	0.0187	0.0943
C	5	0.0702	0.023	0.0986	0.00973	0.234	0.01	0.244	0.0855	0.0167	0.102
D	5	0.137	0.092	0.12	0.0145	0.301	0.045	0.346	0.113	0.0682	0.181
E	5	0.134	0.121	0.0374	0.0014	0.089	0.103	0.192	0.056	0.105	0.16
F	5	0.047	0.052	0.024	5.74E-04	0.059	0.022	0.081	0.0357	0.025	0.0607
G	5	0.121	0.062	0.14	0.0196	0.322	0.049	0.371	0.0828	0.0572	0.14
H	5	0.124	0.064	0.148	0.0218	0.339	0.049	0.388	0.0968	0.0513	0.148
I	5	0.181	0.116	0.176	0.0311	0.434	0.058	0.492	0.139	0.0888	0.227
J	5	0.176	0.136	0.126	0.0158	0.306	0.071	0.377	0.174	0.08	0.254
K	5	0.396	0.393	0.14	0.0195	0.365	0.206	0.571	0.202	0.3	0.502
L	5	0.24	0.156	0.179	0.032	0.424	0.13	0.554	0.163	0.139	0.302
M	5	0.295	0.292	0.0628	0.00395	0.166	0.227	0.393	0.0775	0.25	0.327
N	5	0.237	0.208	0.14	0.0197	0.339	0.109	0.448	0.217	0.118	0.335
O	5	0.268	0.248	0.106	0.0112	0.267	0.184	0.451	0.099	0.201	0.3
P	5	0.0192	0.013	0.0228	5.19E-04	0.057	0.001	0.058	0.0247	0.004	0.0287
Q	5	0.346	0.331	0.141	0.02	0.363	0.219	0.582	0.154	0.248	0.401
R	5	0.278	0.255	0.0803	0.00645	0.195	0.206	0.401	0.121	0.214	0.335
S	5	0.347	0.294	0.0945	0.00894	0.221	0.27	0.491	0.139	0.28	0.419

Oxidised nitrogen (NOx-N) – (calculated as NO_3-N + NO_2-N, mg/L)

Site	Count	Mean	Median	Std Dev	Variance	Range	Min	Max	IQR	25th%	75th%
A	5	0.078	0.087	0.0343	0.00117	0.09	0.02	0.11	0.0323	0.065	0.0973
B	5	0.0664	0.032	0.0745	0.00555	0.176	0.02	0.196	0.0755	0.0208	0.0963
C	5	0.0722	0.025	0.0993	0.00987	0.237	0.01	0.247	0.087	0.0182	0.105
D	5	0.14	0.097	0.12	0.0145	0.302	0.046	0.348	0.115	0.07	0.185
E	5	0.135	0.123	0.0382	0.00146	0.091	0.104	0.195	0.0565	0.105	0.161
F	5	0.049	0.053	0.0243	5.92E-04	0.061	0.023	0.084	0.0355	0.0275	0.063
G	5	0.123	0.064	0.14	0.0197	0.324	0.05	0.374	0.0825	0.0597	0.142
H	5	0.126	0.066	0.148	0.022	0.339	0.052	0.391	0.0953	0.0535	0.149
I	5	0.186	0.12	0.177	0.0312	0.434	0.063	0.497	0.14	0.093	0.233
J	5	0.179	0.139	0.128	0.0163	0.312	0.071	0.383	0.177	0.0815	0.259
K	5	0.437	0.396	0.158	0.0251	0.404	0.224	0.628	0.231	0.342	0.573
L	5	0.245	0.16	0.179	0.0321	0.427	0.132	0.559	0.163	0.145	0.308
M	5	0.319	0.313	0.0482	0.00233	0.132	0.265	0.397	0.0428	0.293	0.336
N	5	0.243	0.215	0.141	0.02	0.339	0.113	0.452	0.224	0.121	0.345
O	5	0.274	0.255	0.106	0.0112	0.268	0.188	0.456	0.102	0.207	0.308
P	5	0.02	0.013	0.0231	5.32E-04	0.058	0.001	0.059	0.0257	0.00475	0.0305
Q	5	0.358	0.339	0.154	0.0236	0.39	0.227	0.617	0.163	0.252	0.415
R	5	0.283	0.257	0.0817	0.00668	0.196	0.209	0.405	0.127	0.217	0.344
S	5	0.353	0.299	0.0956	0.00914	0.224	0.275	0.499	0.139	0.287	0.426